SCIENTIFIC AMERICAN SUPPLEMENT. No. 1632

Entered at the Post Office of New York, N. Y., as Second Class Matter. Copyright, 1907 by Munn & Co.

Scientific American, established 1845.
Scientific American Supplement, Vol. LXIII., No. 1632.

NEW YORK, APRIL 13, 1907.

Scientific American Supplement. $5 a year.
Scientific American and Supplement. $7 a year.

LIQUID CRYSTALS AND THEORIES OF LIFE.

By Our Berlin Correspondent.

In spite of all the achievements of modern science, it has been so far impossible to give a true definition of life. The views generally held in this respect are being revolutionized by the investigations of Leduc, J. Butler Burke, O. Lehmann, and others, on a supposed transition between living and inanimate matter.

FIG. 1.—THE GROWTH OF CRYSTALS.

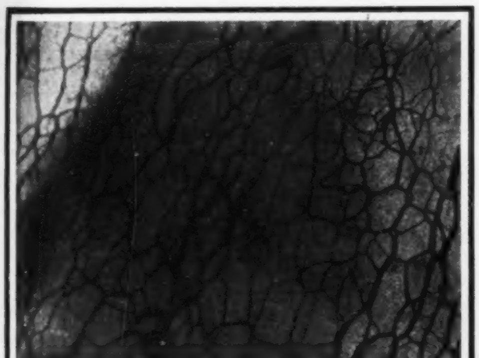


FIG. 2.—CHOLESTERYL BENZOATE, A CRYSTALLINE LIQUID.

FIG. 3.—UNION OF LIQUID CRYSTALS.

FIG. 4.—LIQUID CRYSTALS AS SEEN UNDER THE MICROSCOPE.

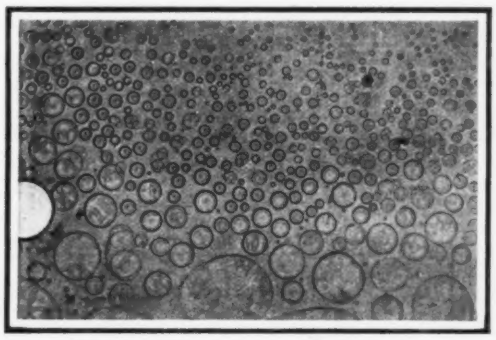


FIG. 5.—CRYSTALLINE DROPS WITH A NUCLEUS.

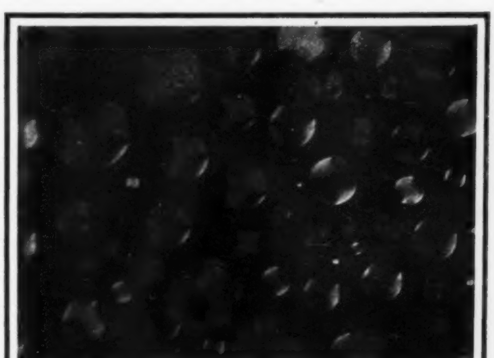


FIG. 6.—CRYSTALLINE DROPS AS SEEN IN POLARIZED LIGHT.

FIG. 7.—LIQUID CRYSTALS WITH DIMINISHED MOLECULAR DIRECTIVE FORCE.

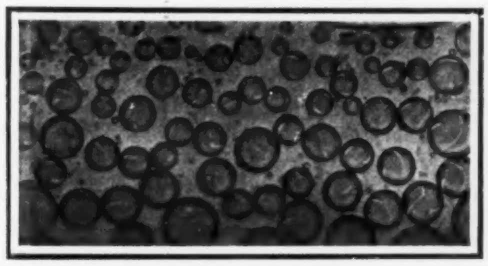


FIG. 8.—OBLIQUE ARRANGEMENT OF MOLECULES, DUE TO ADDITIONAL FOREIGN MATTER.

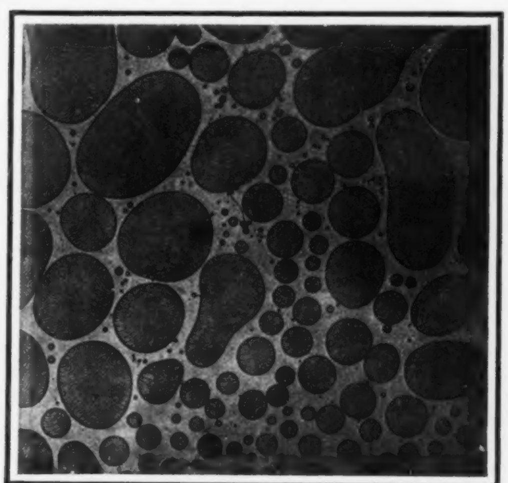


FIG. 9.—DISTURBANCES IN THE CRYSTALLINE STRUCTURE.

LIQUID CRYSTALS AND THEORIES OF LIFE.

In an article recently published in the Scientific American, the writer gave an account of Prof. O. Lehmann's work on what are called apparently living soft crystals. From these investigations it is inferred that there exists a striking analogy between the behavior and characteristics of crystals and those of the lowest living organisms, and that no definite line of demarkation can be drawn between them.

In a lecture delivered at the recent Congress of German Physicians and Naturalists, held at Stuttgart, Prof. Lehmann reviews in a most interesting manner his work in this direction, describing the behavior of liquid crystals in their connection with the theories of life.

The popular view of life consists in ascribing to any living organism two different factors, viz., a body and a soul. However, considering that many cases are on record in which some part of an organism, after being severed from the remainder, continues living independently of the latter, it would seem difficult to uphold this theory, unless the soul of an organism be susceptible of subdivision like the body.

Remote antiquity, which knew nothing of the present atomic theory, populated the whole of the universe with invisible demons supposed to be the causes of natural phenomena: the sun, the sêa, the wind, in fact any river, spring, or tree, would be connected with some deity, some invisible being endowed like man with a free will. Observation, however, continually afforded striking evidence that there are definite laws of nature, and the demons finally shrank to *atoms*, which are as unable to avail themselves of their will as a moth that under the impulse of irresistible instinct rushes toward a luminous flame, there to be burned.

While atoms are thus images of our own selves, they may very well be really existent. Even those who abandon all idea of understanding the phenomena of nature are compelled to suppose the hypothetical existence of atoms, there being a multitude of phenomena which could not be otherwise described unless many new words were invented.

While limiting ourselves to stating that the phenomena of nature behave as if bodies were composed of atoms, we are free to give rein to fancy, and to consider these minute invisible demons as some sort of living organisms of the lowest order. As a matter of fact, the most recent investigations on the passage through matter of Lenard, X, and radium rays, would seem to show that atoms as defined by chemists, instead of being the ultimate particles, are in turn made up of still smaller "elementary particles" situated at relatively considerable distances apart, and that there is even extremely violent motion within the atom, resulting in the liberation of enormous amounts of energy during the disaggregation of radium atoms. If this be true, the above hypothesis would have to be modified only slightly, atoms being replaced by these "elementary particles" as the ultimate infinitely small components of matter.

While these elementary particles could not possibly possess any one of those properties which are regarded as characteristic of life, especially the automatic control of all functions, it should be remembered that these properties exist only to a rather limited degree in many living organisms. Prof. Lehmann therefore suggests the existence of what he calls *latent life*, in which no vital functions are really performed, while the capacity of such functions is preserved. He thus

arrives at Haeckel's monistic theory, according to which all matter is alive, the more elevated living organisms being only associations of elementary beings, as a people or state is an association of many individuals, indebted for its increased power to the united working of its different parts. Death, then, would be the separation of these various components and not a severing of the body from the soul.

Now, although the formation of associations is a comparatively simple matter in human life, the aggregation of simple individuals to complex ones in nature is practically never observed, while the aggregation of atoms, to form even bacteria (that is, *spontaneous generation*) seems to be entirely impossible,

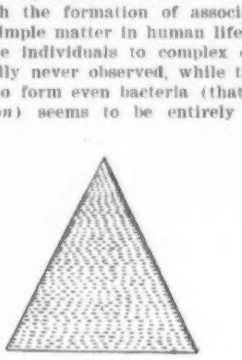


FIG. 10.—A LIQUID CRYSTAL IN THE FORM OF A HEMIMORPHOUS PYRAMID.

though there actually exists a tendency of atoms to aggregate together. But all such aggregations of atoms produce crystals, not living beings unless crystals are considered as living beings.

According to Haeckel, indeed, there is a close relationship between crystals and the lowest living organisms. There are unquestionably numerous analogies in the behavior of the two, which must strongly impress any observer who studies crystals, not in their completed state, in the mineralogical museum, but when in the making.

The faculty of growing in itself constitutes such an analogy, no amorphous body (glass, resin, etc.) being capable of growing, while in the case of crystals the outward appearance of real organisms is often imitated (Fig. 1). Crystallized debris of sodium naphthionate in aqueous solution, after being dissolved by heating, appears on cooling in the shape of plates pos-

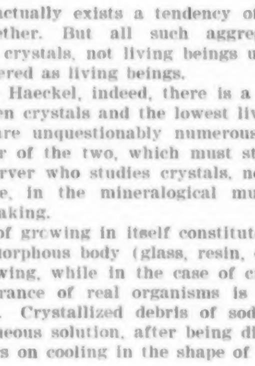


FIG. 11.—A ROUNDED PYRAMIDAL FORM.

sessing definite angles and edges. Crystals are thus endowed with a certain *recuperative power*, that is to say, with a capacity for healing injury. In fact, any fragment of a crystal, be it ever so small, will act as a nucleus of crystallization comparable to the germ of an organism.

Another remarkable fact is that crystals, like living beings, are capable of devouring each other. From a strongly supersaturated solution there are deposited, at first, crystals of extraordinary size and shape, suggesting monstrous leaves; after some time ordinary crystals appear here and there, and these crystals, owing to their smaller solubility, actually devour the larger ones previously formed.

Another analogy between crystals and living organisms is that the former, like the latter, are capable of absorbing foreign matter. If, for instance, iron chloride is added to a solution of sal ammoniac, the solution as well as all the crystals will be colored reddish yellow, but the hue of the crystals will be considerably darker than that of the solution, the coloring matter being attracted by the crystals. The latter actually suffer a sort of *poisoning*, the fir-like structures of Fig. 1 being reduced to the peculiar formations shown in Fig. 2.

In spite of the numerous analogies which exist between crystals and organisms, some important differences can also be stated. In the first place, living organisms are soft and sometimes liquid albuminoid structures, whereas crystals may be regarded as typically rigid bodies, the existence of liquid crystals having never been suspected until quite recently. In fact, the difference seems to be as great as that between colloids and crystallized bodies.

Theory seems to prove the impossibility of the existence of liquid crystals. In the gaseous state, molecules move in straight lines, while in the liquid state they move among each other like worms without any apparent order. In amorphous solidification the motion ceases, but the irregularity persists; whenever crystals are formed, their particles are arranged in a regular system of points or "space grating," the isotropical structure being converted into a non-isotropical one. The special aggregation of the molecules (that is to say, the condition of the space grating in crystals or the absence of any regular arrangement in the case of amorphous solidification) determines the properties of the particular modification of the body, which modification, like the liquid or gaseous state, should be considered, not as another substance, but rather as another state of aggregation.

A crystal cannot therefore be liquid, like a drop of water or oil, nor can it be made to flow by the action of external pressure, as any continuous relative displacement of the particles would result in an alteration of the arrangement in space, that is to say, of the properties of the body. While molecules always maintain their tendency to assume a regular arrangement, they are usually unable to yield to this tendency, their internal friction preventing any molecular conversion. Only in the course of long intervals of time, under the action of long-continued shocks, can this internal friction be overcome and the original condition, e.g., of wrought iron, be restored, the latter resuming its original crystallized condition and altering its properties in a way most undesirable to the engineer.

The arrangement is sometimes converted to another crystalline figure, while the outward appearance sometimes undergoes alteration. Yellow mercury iodide, for instance, becomes red on being compressed or scratched, passing into a modification characterized by quite different properties. Brown sulphur, a long time after being cooled to ordinary temperature, exhibits yellow spots that spread slowly throughout the mass, until the latter is converted into the dimorphous yellow modification. The slowness of this molecular conversion clearly illustrates the existence of internal friction, which has to be overcome during the transition from one state to the other. In fact, both the yellow and brown modifications can be heated to melting without producing any conversion, the latter being brought about only by mechanical force.

The above are the views which are generally adopted in treatises and which until a short time ago were generally considered true. Prof. Lehmann, however, as long as thirty years ago, was engaged in investigating the dark yellow modification of silver iodide produced by heating above 146 deg. C. While this modification, being a good conductor of the electric current, was regarded as a viscous liquid, Lehmann ascertained by observation that the material is an aggregate of extremely soft regular octahedral crystals, which flow under the action of pressure as if they were liquid. In spite of the thorough alteration in the arrangement of particles, the properties do not approach those of the amorphous state; in fact, the crystals continue growing as before, while maintaining their well-defined melting point, whereas amorphous bodies are softened gradually, and exhibit no growth. Nor could any sudden alteration be noted in the properties of the substance. According to existing theories, the only admissible hypothesis was that the crystals are reduced to minute needles, invisible even under considerable magnification, the arrangement in space being preserved and the connection of particles being maintained by an adhesion, equivalent to cohesion. Now, such a process should be attended by an increase in volume and by turbidity. Neither, however, was observed. The debris must therefore consist of single molecules, proving that in opposition to the then prevalent theories, the arrangement in space of the particles can be destroyed at will without any considerable alteration in properties. The above theories were thus shown to be incorrect. On the other hand, the existence of a well-defined temperature of conversion was shown by the crystallization microscope, provided the two modifications be kept in intimate contact. From the above the conclusion was drawn that the polymorphous conversion, instead of being produced by an alteration of the "space grating," was due to an alter-

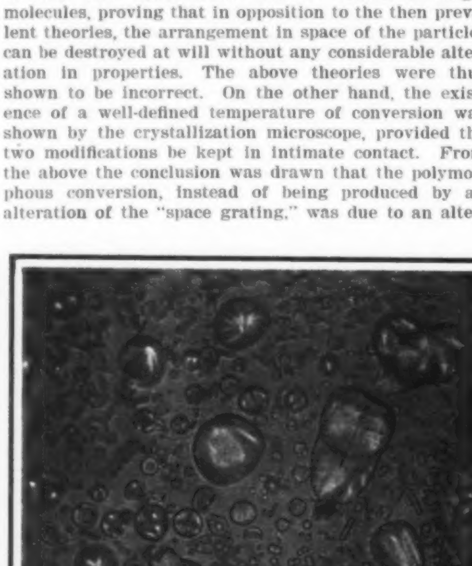


FIG. 14.—FORM ASSUMED BY A DOUBLE DROP.

LIQUID CRYSTALS AND THEORIES OF LIFE.

ation in the molecules themselves produced by unknown forces. This hypothesis was confirmed by observing that dissociation as well as the recuperation of loose chemical compounds are processes quite analogous to polymorphous conversion. This theory could thus be extended to the liquid and gaseous states. Amorphous modifications next were found to constitute irregular molecular aggregates, consisting of different kinds of molecules. The crystals or silver iodide should therefore be regarded as *really liquid crystals*. Though the existence of such crystals is still ignored by the textbooks, no less than fifty substances are now known to form them. Further evidence of their existence was afforded by the following observation:

According to an experiment made by Plateau for the demonstration of surface tension, an oil drop floating in diluted alcohol will assume a perfectly spherical shape and return to this shape after any deformation. When divided into several droplets, each portion at once forms a sphere, and the contact of two or more drops again results in the production of a perfect sphere. Now Prof. Lehmann in 1888 found a sub-

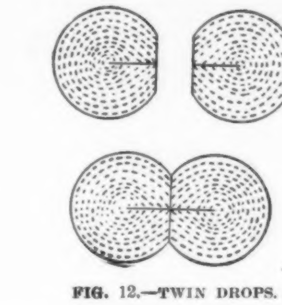


FIG. 12.—TWIN DROPS.

stance (cholesteryl benzoate, discovered by Reinitzer, Fig. 2) actually containing in suspension liquid drops of crystalline shape, which were originally considered as solid crystals produced on cooling. An interesting instance of such liquid crystals is the para-azoxybromine phenic acid ethyl ester discovered by Vorländer, of which a view as seen under the microscope is given in Fig. 4. These crystals, though liquid, are not, like the oil drop above referred to, compressed to a sphere under the action of surface tension. This is obviously due to some force of yet unknown nature, which may appropriately be called morphogenetic force.

While the existence of a certain amount of internal friction has been frequently considered as characteristic of solid bodies, liquids also possess such friction.

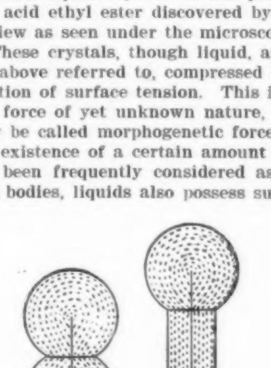


FIG. 13.—ANOTHER FORM OF DOUBLE DROP.

A silk thread suspended in a liquid of the same density will be compressed to a sphere only after a very long time, the surface tension finally overcoming the action of internal friction, which is proportional to the velocity of motion. A liquid crystal, however, permanently keeps its shape. The force above referred to cannot therefore be identical with internal friction. Nor can it be rigidity or torsional elasticity, as this only preserves a shape once imparted to a body, but is unable to produce any change of shape.

As regards a possible connection between morphogenetic force and expansive force (or osmotic pressure) with which, according to the kinetic theory, every liquid is endowed in virtue of the state of motion of its molecules, it might be presumed that, owing to differences in surface tension, the shape of liquid crystals would differ from that of a sphere. This difference in surface tension, however, would produce continuous currents within the crystal, and the only admissible explanation is that the force of expansion exerts actions of different intensity in different directions, while the shape of the molecules themselves is different from that of a sphere. It has been urged that in a liquid drop containing highly anisotropical molecules there is a molecular directive force, producing the anisotropy in structure and accordingly in expansive force, in virtue of which a polyedric form is produced, as in the case of solid crystals. This is confirmed by the double refraction and dichroism of liquid crystals as well as by the fact that in the case of a mechanical deformation a forced homeotropy of liquid crystals can be obtained, the alteration in internal structure being attended by an alteration in external shape.

These phenomena are especially striking in the case of para-azoxy-phenic-acid-ethyl-ester, the liquid crystals of which take the shape of uniaxial prisms, appearing white in the direction of the axis and yellow in all other directions. If an aggregate of such crystals is compressed between two glass plates, the whole mass will become white, appearing dark between crossed nicols and thus proving that the molecules have been arranged everywhere with the optical axis at right angles to the glass plate. This can be accounted for only on the hypothesis that the molecules take the shape of leaves, the optical axis of which is perpendicular to their surface. If this whitened mass is heated, yellow spots are formed wherever it is melted, the surface tension again making itself felt in those parts.

In some other cases only a molecular directive force, but no morphogenetic force, is observed; in fact, some

liquid crystals take the shape of perfectly spherical drops, although they possess an entirely regular internal structure. When observed in a given direction, such drops will show a dark nucleus in the center (Fig. 5), while in a direction at right angles to the former a biconvex lens is seen. Neither of these figures really exists, both being produced by the effects of refraction.

Two crystal drops, on coming into contact with one another, combine like two water drops, showing for some time two nuclei between which there is a dark point of different shape. The structure, however, gradually becomes entirely uniform, only one nucleus being left. This flowing together of two crystal drops to a uniform individual can be regarded as analogous to the copulation of lower organisms.

In the magnetic field the drops are found to rotate until their axis of symmetry agrees with the magnetic lines of force; furthermore, their structure is altered in such a way that the axes of the various molecules as far as possible approach the lines of force. Any disturbance in a structure artificially produced in the drop instantaneously disappears in virtue of the spontaneous homeotropy. The rotation of molecules does not require any appreciable expenditure of energy, their mean distance remaining unaltered.

The molecules in the interior of the liquid crystal are influenced in their arrangement by the orientation of the surface molecules, which is due to the surface tension. Any disturbance in the latter will correspond with an alteration in the inside structure of the liquid crystal. The force of absorption of the glass, for instance, will set the optical axis at right angles to the glass whenever a freely floating drop comes into contact therewith.

If the molecular directive force of the crystal is diminished by addition of some other substance, the absorbing force of the glass will, even in the case of a solvent, exert so intense an action as to produce darkness as far as the edges of the drop between crossed nicols, the optical axis being set everywhere at right angles to the surface of the glass (Fig. 7).

The absorption of foreign matter by liquid crystals entirely corresponds with the formation of mixture crystals in the case of solid bodies. If the absorbed component is colored the influence of molecular directive force on its molecules can be inferred from the dichroism of the colored liquid crystals. The structure of crystal drops is furthermore subjected to considerable disturbance by the addition, e.g., of resin, as the growth of solid crystals is interfered with by the absorption of certain components. An oblique arrangement of the molecules (see Fig. 8) is thus produced, as inferred from the deviation of the direction of maximum absorption and the rotation of the plane of polarization. If, on the other hand, the substance added possesses great morphogenetic force, it may increase that of the original substance. Such mixture crystals may be considered as real solutions, as any one of the substances is able to diffuse into the other.

If two such crystalline liquids are miscible in all proportions, as in the case of isomorphy, the surface tension at their boundary should be zero. The force of expansion of one medium cannot, however, produce a deformation of the boundary, owing to the equivalent force of expansion of the isomorphous medium. The dissolved substance, according to Prof. Lehmann's views, might even be another liquid crystalline modification of the same substance. If such a substance is melted and then cooled, the liquid crystalline modifications in question are produced successively at two different temperatures.

If such a mass of apparently isotropical structure is cooled to the temperature of conversion, striking color phenomena, resembling the iridescence of the wings of butterflies, are produced both in ordinary light and between crossed nicols, all the colors of the spectrum being gone through successively from the violet to the red.

The miscibility of two liquid crystalline modifications (excluded by the old continuity theory) is difficult to understand, as in the case of an intimate contact between two modifications, unless the temperature is the exact point of conversion, the unstable modification should be converted into the stable one, thus giving rise to the production of only one modification. This difficulty is eliminated, however, by considering that the temperatures of dissolved molecules may very well be different, thus giving rise to continual conversions in either direction as in other cases of chemical equilibrium.

If in a liquid crystal a similar crystalline dissociation is produced, this necessarily exerts an influence on the morphogenetic force. Similar phenomena possibly occur in the case of solid crystals, thus accounting for the frequently remarkable variability in the shape of some crystals. While ordinary solid mixture crystals cannot be formed by mutual diffusion of components, there is no difficulty in preparing liquid mixture crystals by mechanical mixing. Such "copulation," as it were, between individuals of different kinds, in the province of biology, results in the formation of hybrids or crosses; but crossing is possible also in the field of liquid crystals, when mixture crystals and, in the case of considerable differences in structure, striking disturbances in structure (Fig. 9) will be obtained.

The substance called para-azoxy-phenic acid ethyl ester shows some quite remarkable phenomena. The liquid crystals formed by it are normally hemimorphous pyramids (Fig. 10). When separated at a somewhat lower temperature (that is to say, from a less concentrated solution), the crystals seem to absorb some of the solvent, thus becoming more liquid. Their shape at the same time more closely approaches that of a sphere (Fig. 11), while a depression remains at the base of the pyramid. From this depression a peculiar band goes toward the center of the sphere. Two such spheres, when combined with their depressions in corresponding positions, will produce one drop of the same kind, while in the case of opposite positions the drop produced by combination shows two depressions (or more, according to the number of drops combined). If, however, the depressions of two drops come into contact, they simply adhere to each other, forming a twin drop (Fig. 12). Such twin drops are also produced without any apparent external cause, a bud arising from the depression of a drop and separating from the latter as soon as a certain size is reached. This is no doubt analogous to the propagation by budding observed in the case of living organisms. A

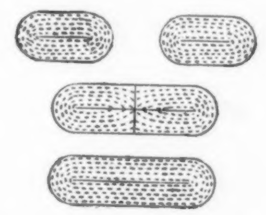


FIG. 16.—THE BACTERIA-LIKE SEPARATION.

double drop, however, is apt to extend to a small bacillus-like rod (Fig. 13) or else to a long serpentine form (Figs. 14 and 15). In fact, its growth, like that of living organisms, is due to some sort of internal absorption, its thickness always remaining constant, whereas an ordinary crystal expands owing to the addition of new particles to the surface. Furthermore, these small rods are able to creep forward and backward like bacteria, while performing serpentine motions or rotating round their axis. Their most remarkable property, however, is their ability to separate like bacteria into two or more portions (Fig. 16) which act like complete individuals and grow and separate in the same manner.

These liquid crystals, the existence of which had been doubted by physicists and crystallographers, thus greatly increase the analogies between crystals and living beings. While partisans of *monism* will feel gratified by this discovery of a transition between crystals and living beings, foreseen by them and confirming their theories, those of *dualism* are likely to consider the existence of a continuous transition between liquid and solid crystals as proof of the fact that the forms in question possess only apparent life. They will regard these facts as demonstrating the correctness of their theories, showing that many phenomena which had so far been considered as manifestations of life, are based on merely physical and chemical effects. By further investigating the phenomena in question, it would become possible actually to ascertain what effects are really produced by energy and matter, and where life proper commences.

Independently of the final results of this dispute, the physicist will welcome its leading to a thorough investigation of phenomena that show the effects of molecular forces and the molecular constitution of matter.

Even practical results can be expected from these investigations. Our heat motors are imperfect machines which provisionally convert the high-grade

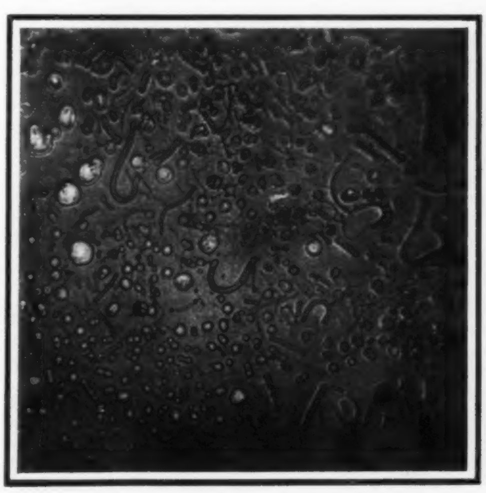


FIG. 15.—A DOUBLE DROP EXTENDED TO A LONG SERPENTINE FORM.

LIQUID CRYSTALS AND THEORIES OF LIFE.

chemical energy of carbon into low-grade thermic energy. Organisms are far more efficient in this respect, and should we succeed in imitating their muscular apparatus, steam engines would be done away with entirely, a novel kind of machine based on the working of soft and half-liquid substances being developed; it might even become possible to design an extremely light yet highly efficient motor, the lack of which has so far been the greatest obstacle to the realization of flight.

BERTHELOT.

By F. Ashford White.

In the remarkable discourse pronounced by M. Jules Lemâitre at the "reception" of Berthelot as member of the French Academy, the celebrated writer referred to the two French "kings of chemistry"—Lavoisier, typifying analysis; Berthelot, synthesis. It would be premature at the present moment to draw a parallel between the two illustrious chemists. Certain it is that Berthelot had a certain cult for Lavoisier; it was in a large measure by his exertions that the present handsome statue of the noblest victim of the guillotine was erected in the center of Paris. Berthelot remarks, in one of his works, that he never had the pleasure of personally meeting Madame Lavoisier, but that he had known Madame Laplace, and felt the subtle charm of the *ancien régime*. Berthelot was the "grand old man" of French science, the link between the old monarchical days and the modern republic. When he was born (in the Place de l'Hotel de Ville, Paris, in 1827) the last of the Bourbons still reigned in the Tuileries; his school days were the epoch of Louis Philippe, and it was a twelvemonth before the *coup d'etat* of 1851 placed Napoleon III. on the throne of France that Berthelot entered the laboratory of Balard at the College of France as preparator. His appointment as professor of organic chemistry at the Paris Superior School of Pharmacy (1859) was signed by the Emperor Napoleon. He frequented the salons of the Princess Mathilde, and it was, it is whispered, partly by her influence that the chair of organic chemistry at the College of France, of which Berthelot was the first titulary, and which he occupied until his death, was created in 1865. On September 2, 1870, two days before the Second Empire fell, he became president of the Scientific Committee for the Defense of Paris, taking up the study of explosives in the same thoroughgoing manner as he did every other subject he touched. He was elected a life senator of the republic in 1881, was Minister of Public Instruction for a few months in 1886, and Minister of Foreign Affairs for a similar brief period in 1895-6. The Academy of Medicine elected him member in 1863, the Academy of Sciences in 1873. In 1889 he succeeded Pasteur as perpetual secretary of the latter body. He was present at the usual Monday afternoon meeting only a few hours before his death, which took place in the apartments he occupied in the Institute of France.*

The landmark of his life was 1854, when he took his Sc.D. degree with his thesis on "The Combination of Glycerine with Acids, and the Reproduction of Natural Neuter Fatty Bodies." During his professorship at the Paris School of Pharmacy (1859-1876) he published a two-volume "Organic Chemistry Founded on Synthesis"; two more volumes on "General Methods of Synthesis"; one of "Lessons on Sugared Principles" (*principes sucrés*); another on isomerty; a work on explosives; his "Elementary Treatise on Organic Chemistry," and (in 1875) his celebrated work on "Chemical Synthesis." Later in life he turned his attention to thermo-chemistry, and in 1879 published his "Essay on Chemical Mechanics" founded on this science.

The favorite hobby of his leisure hours was the study of the history of alchemy and chemistry. His first volume on this subject, "The Origin of Alchemy," appeared in 1885; in 1887 this was followed by "The Ancient Greek Alchemists"; and in 1889 by the "Introduction to the Study of the Chemistry of the Ancients and the Middle Ages." Between 1850 and 1888 he published six hundred essays, papers, etc.

In his family life he was singularly fortunate. His wife was a remarkable woman, to whom he was sincerely attached, and whom he survived but a few minutes. They brought up four sons, who are not unworthy followers in their father's footsteps in the paths of politics and science, and two daughters, who married distinguished professors. A group of sunny-haired grandchildren often graced the big garden at the Institute of Vegetable Chemistry which the French government had founded (just outside Paris) for facilitating Berthelot's studies on the fixation of nitrogen and the problems of vegetation. This was the aged savant's favorite residence, combining as it did his two special interests and delights, the privacy of a laboratory "far from the madding crowd" and the privacy of family life, which he infinitely preferred to the dreary round of public or social functions.

Grand Officer of the Legion of Honor, an "Immortal" of the French Academy, senator and minister as already mentioned, Berthelot was one whom his countrymen delighted to honor. The simplicity of his home life, the disinterested character of his work—he could have made millions by patenting his discoveries—and his many sterling qualities endeared him to all sections of the community. Abroad his merit was recognized by his election to many scientific bodies, but Frenchmen are sorely puzzled by the fact that Berthelot died without becoming a Nobel prizeman.

In cytological investigations, Fischer's work on the artificial production of effects resembling those seen in fixed protoplasm should be borne well in mind. This work is timely, and may assist in checking irrational developments by forcing a proper regard for a comparison of the effects observed in fixed tissues with those shown by the living material. There are, moreover, but few directions in which the study of metabolism and metabolic products may not profit from

* The secretaries of the various academies are allotted official residences in the building itself.

cytological research. A notable instance of what there is to be done is well indicated by the work of the late Dr. Timberlake on the division of plastids and the development of the starch grain.

[Concluded from SUPPLEMENT No. 1631, page 26134.]

THE NEW INLAND SEA.*

By ARTHUR P. DAVIS, Assistant Chief Engineer, U. S. Reclamation Service.

THE RETREATING CATARACT.

THE deep channel in the Alamo River, which passed Holtville in August, was gradually approaching Sharp's Heading, and it was recognized that when this cataract reached the heading it would be very difficult and expensive, and perhaps impossible, to maintain that heading. This, however, was not the only peril to the water supply of the valley. The channel of New River had eroded to such an extent that where the two streams separated it was estimated that four-fifths of the water was running down New River and only one-fifth down the Alamo. While this proportion was favorable to the regimen of the Alamo and the safety of Sharp's Heading, it was very threatening in another respect. It accelerated the cutting of the New River channel, in which was a great cataract four or five miles below the separation of the two streams, and this was, of course, advancing upstream. It was well recognized that when this cataract reached the Alamo the channel would be so deep that all of the water would run down New River and leave Sharp's Heading on dry land, without any water for the irrigation of the Imperial Valley. Threatened first with inundation, and next with the destruction of their entire water supply, the inhabitants of the Imperial Valley have naturally been almost in a state of panic for several months.

THE SAFETY OF $100,000,000 IN THE BALANCE.

The continuation of the flow of the Colorado River into the Salton Sea meant the gradual inundation of the entire Imperial Valley. Whether the lake would ever rise high enough to actually flow out through Volcano Lake to the Gulf of California is problematical. Volcano Lake is about 30 feet above sea level. Taking the mean annual discharge of the Colorado River at 9,000,000 acre-feet and the evaporation at 6 feet in depth per annum, the lake would fill in forty to fifty years and would flow a considerable stream perennially into the Gulf of California. But taking the more probable values of 8,000,000 acre-feet for the mean annual inflow and 7 feet in depth for the mean annual evaporation, the depression would never fill. It would rise to a point 8 or 10 feet above sea level and oscillate above and below this level in accordance with the fluctuating annual discharge of the Colorado River.

Either result, however, would have been destructive of enormous interests. It would have submerged 150 miles of the railroad track of the Southern Pacific road, and would have required extensive alterations of its alignment in the vicinity of Yuma. The rapid erosion of the channel leading to the Salton Sea would advance upstream slowly but surely. It has already cut the channel at Yuma two or three feet below the former level. This cutting would be continued until the 200-odd feet of excess fall in the channel had been distributed up the Colorado River, eventually, perhaps, as far as The Needles. It certainly would have cut a deep channel up to Parker—so deep that it would probably have been entirely impracticable to dam and divert the Colorado River at any point below Bill Williams Fork, and thus it would have become impossible to irrigate the great valleys of the Colorado River. These valleys aggregate about 400,000 acres. It is estimated that there are 300,000 acres of fertile irrigable land in the Imperial Valley and twice as much more in the Colorado delta in Mexico. The lands referred to are now settled by a population of 12,000 to 15,000 people, most of whom would have had to abandon their homes.

It may be said, therefore, that during the past year the fate of 700,000 acres of fine irrigable land, in a semi-tropical climate, the homes of over 12,000 people, and 150 miles of railroad track have been trembling in the balance. It is impossible to assign definite values to all these elements, but $100,000,000 would not be an overestimate.

The railroad company spent immense sums of money in repeated removals of its tracks, as the shores of the Salton Sea grew higher and higher, and also experienced great difficulty in preventing the destruction of its bridge across the Alamo River, as the channel cut deeper and wider. The railroad company appreciated the gravity of the situation in the summer of 1905 and made a large loan to the irrigation company for the purpose of damming the channel. Repeated efforts to do this were unsuccessful, and the control of the irrigation company passed into the hands of representatives of the railroad company. About one year ago the construction of a dam across the new channel was in progress, and strong hopes were entertained by the railroad people of the success of the attempt, when a very large and unexpected flood came down the river, which carried away the works and left the situation more threatening than ever. As soon as the water subsided sufficiently the efforts were renewed and continued throughout the spring of 1906 without success. When high water came in May the company was obliged to abandon its efforts until after the flood season. The heavy discharge of the river during May, June, and July nearly all went down the Alamo and New rivers and cut the channels larger and larger. The railroad south of the Mexican line was entirely washed away, the former site finally becoming a deep channel.

THE GREAT SALTON SEA, 205 FEET BELOW SEA-LEVEL AT THIS POINT, NEAR THE SALTON STATION ON THE SOUTHERN PACIFIC RAILROAD.

Brush dam at the headworks of the California Development Company's dam in the Colorado River, just below the old river bed.—From the National Geographic Magazine.

THE NEW INLAND SEA.

THE DESTRUCTIVE CATARACTS.

The cataract in New River advanced upstream past Calexico, took away some of the buildings of that town, and nearly all of the buildings of the Mexican village of Mexicala, and continued to advance eastward at a threatening rate. The Alamo River cut back similarly, and in August, 1906, the cataract had passed the town of Holtville and caused the temporary shutting down of the power plant at that place. In the endeavor to prevent the destruction of valuable buildings and farms, the people made strenuous attempts to guide the cutting of the water by the use of dynamite to assist the cutting where it would do less damage than if left to its own inclinations. It is not apparent, however, that any great benefit resulted from these attempts. During the high-water season of 1906 the irrigation company made two plans for the diversion of the destructive waters. One of these, the success of which was relied upon, was the construction of large headgates, at the foot of Pilot Knob, substantially as originally planned by the engineers. It was planned to dig a channel from the river above these headgates large enough and deep enough to divert the water without very much obstruction and carry it to the Alamo River below its junction with the Colorado. This would leave the new channel dry and permit a dam to be built there and levees along the river to close the disastrous break. This work, however, required a very large amount of excavation, estimated to cost nearly a million dollars. The headgates were built, but no sufficient machinery was available for the excavation, and the construction of a mammoth dredge was undertaken at Yuma. This dredge, mounted upon an enormous pontoon, was to have a capacity of lifting about six tons of material at once, and is now finished and at work.

Realizing the large amount of time that would be required for this excavation, and in the face of the heavy cost of repeatedly moving its track onto higher and rockier ground along the Salton Sea, the company concluded to make a preliminary attempt to dam the new channel by constructing a by-pass around the proposed dam site, through which the water could flow as the dam raised it higher and higher. Wooden headgates were built in the by-pass, and in August the construction of the dam was commenced.

DESPERATE ATTEMPTS TO REGAIN CONTROL.

At this period the situation looked very gloomy; every condition was unfavorable; the river, instead of coming down to its normal low water, was discharging nearly twice as much water as it ordinarily does at that time of year. The large amount of construction in progress in the Southwest made it extremely difficult to obtain and keep laborers in the hot climate and primitive surroundings of a construction camp. The great heat also made it extremely difficult to employ animals to advantage in excavation or transportation of material. The heavy demands made upon rolling stock made it very difficult and expensive for the railroad company to transport materials for this construction; but, in spite of all these difficulties, the officials, with commendable energy, poured money and men into the breach with an unstinted hand, with the determination to make this effort successful. It was recognized that the work was daily becoming more difficult; the channel was cutting deeper and deeper, and if the river were not controlled during the present low-water season it probably never could be, as another high-water season would cut the channel so deep that, without rock foundation or any means of holding a large structure, it would be impossible, or at least enormously expensive, to accomplish the work the following or any subsequent year.

A railroad was built from the main line to the proposed dam site and continued across the river on piling; a large camp was constructed and laborers assembled; huge pile drivers and dredges were brought to the ground, and piles were driven at intervals across the channel where it was proposed to build the dam. At points about 500 feet apart in the river and along the located line of the trestle, two bulkheads were built, one composed mostly of rock and brush on the south side, and the other almost entirely of fascines, on the north side. A mat 100 feet long, up and down stream, was placed on the bottom between these abutments, the piles of the trestle pinning the mat to

* An address to the National Geographic Society, published in the National Geographic Magazine.

the bottom. Over part of this mat a second mat was placed.

Immediately after the construction of the railway across the river the operation of building the remaining 500 feet of dam between the two abutments was begun. Steam shovels loaded 40-yard automatic dump cars at quarries four miles away, and train loads of these cars were run out on the trestle and dumped into the river upon the mat. Gradually the river rose, until on October 10 the difference in elevation of the water above and below the dam was six feet, and practically the whole river was flowing through the gates.

The engineers in charge had detected cutting in front of and below the gates, and in anticipation of their failure had built a trestle across the river above the gates, with the intention of dumping in enough rock to partially close the gates and relieve the situation there. At 3:15 on Thursday, October 11, a large part of this gate, known as the Rockwood gate, went out. The river rapidly scoured a deep channel, lowering the surface of the water above the dam until there was only a difference in elevation of about three feet. Work was immediately begun on repairing the trestle below the gates, which had been injured both by the increased flow and by the timber carried away from the gate. From all the available quarries within a radius of from three to four hundred miles, rock was hurried to this point and dumped rapidly from the lower trestle. At the same time the trestle which had been started above the gates was strengthened, and as soon as it was in shape cars were run out on that and rock dumped in. In the meantime part of the material that had been dumped between the two abutments in the river and over which the overflow had taken place was removed and gradually the channel through the Rockwood gate was filled up.

When this was entirely filled, so as to throw the entire flow of the river over the central portion of the dam, the filling of this portion was again resumed. Large blocks of granite weighing several tons, as well as smaller material, was hauled out as rapidly as trains could bring it and gradually the gap was closed.

The river during all this time did not go below about 9,000 second-feet, adding materially to the difficulties expected.

On November 1 there was an 11-foot difference in the elevation between the water below and above the dam and about one-half the water in the Colorado was going down its old channel. By noon of November 4 the dam was high enough so that practically the entire flow of the Colorado River was returned to its old channel, and since this time the work has steadily gone on raising the dam and riprapping its upstream and downstream slope.

Great credit is due to Mr. Epes Randolph, general manager, and Mr. H. T. Corey, engineer in charge, for the energy and skill with which this work was handled.

HOW SOON WILL THE LAKE DRY UP?

The area of the present Salton Sea is over 400 square miles, and its depth about 90 feet. If the river discharges no water into the sea, it will probably dry up in about ten or twelve years.

Levees must be built along the entire western bank of the Colorado River from Pilot Knob to high ground far into Mexico, probably 15 to 20 miles, because if high water ever overflows this river again and reaches the deep channel which now exists there, it will rapidly erode the channel back to the river and the disaster of 1905 will be repeated.

In order to prevent the Imperial Valley being deprived of water for irrigation, it is necessary to build a new canal from the headgates at Pilot Knob to the channel of the Alamo River. This can doubtless be completed in a few months, and some water is already flowing through the old Imperial Canal, which is approximately along the same line, so there is no danger to the people of the Imperial Valley.

Some persons have suggested that the existence of the Salton Sea during the past year has had a tremendous effect upon the climate in that vicinity in Arizona, and even as far east as Texas and New Mexico. Much publicity has been given to this idea, it having been caught up by newspapers as something worthy of a story.

The absurdity of any such idea may be inferred when we notice that only a short distance to the southward of the Salton Sea occurs the great inland Gulf of California, which is hundreds of times larger than the Salton Sea, and yet there is no very marked influence upon the climate. Besides being so much larger, the Gulf of California is somewhat nearer Arizona, New Mexico, and Texas and is separated from them by fewer mountain chains. If any influence could be exercised by the Salton Sea, hundreds or even thousands of times as much influence would be exercised by the gulf itself; yet no such influence can be detected in that vicinity.

Those who hold to this idea apparently ignore or neglect the fact that the same causes that have led to the creation of the Salton Sea have led to the cutting down of the bed of the Colorado River and the prevention of its normal annual overflow at Yuma and all points below there. The great delta, therefore, which is annually overflowed under normal conditions has received no such overflow since the river has been running into the Salton Sea, at least during the past high-water season, and this fact itself would counteract any influence that might have been exerted by the evaporation from the surface of the Salton Sea.

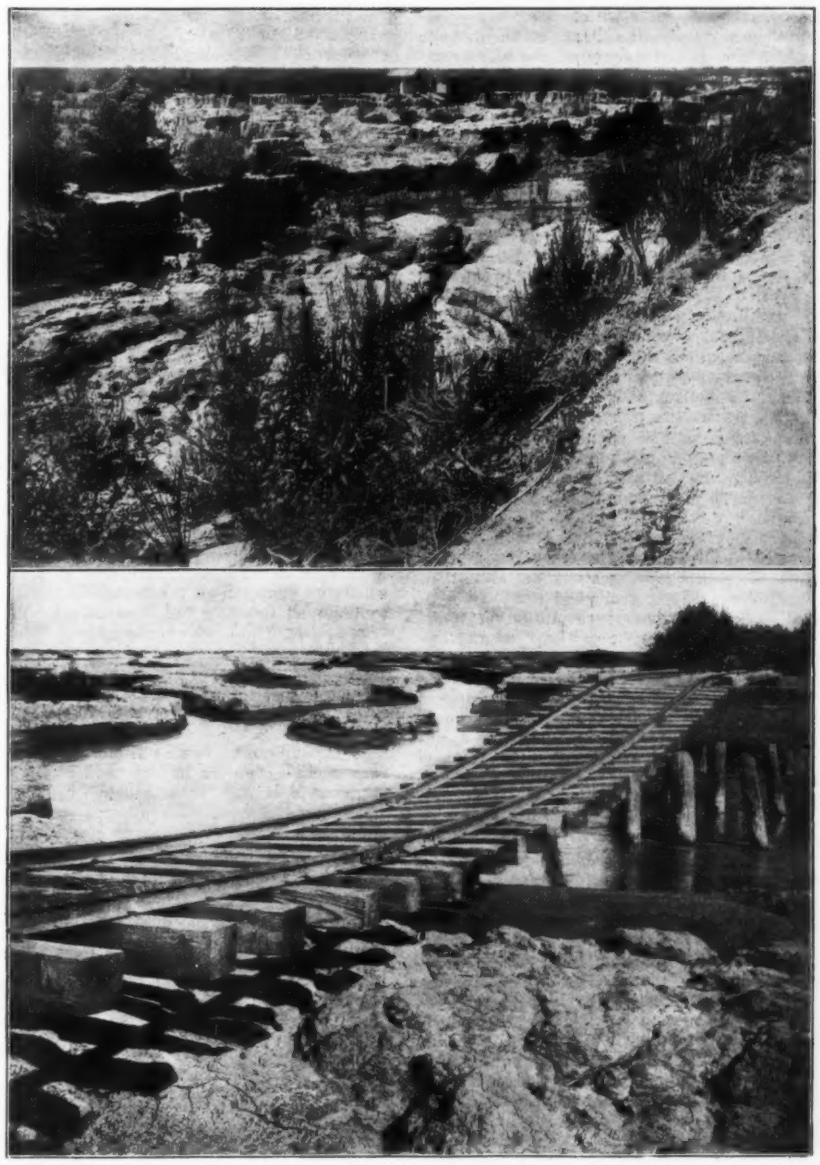
Climate is the result of great cosmic influences so great and extensive that the Salton Sea would be a negligible quantity beside them.

CONDITIONS WORSE THAN BEFORE.

A few days after this address was delivered, the Colorado River worked its way around the dam, which had been built at cost of so much labor and money, and plunged on again to the Salton Sink. The flow of water has been unusually great for this time of year, which complicates the situation. The cataract of the New River has now advanced a long way above Mexicala and is rapidly approaching the Alamo. If the cataract once joins the Alamo the entire Imperial Valley will be cut off from water, and left high and dry until the new Salton Lake has risen sufficiently to inundate the entire region.

Some perplexing questions as to who is responsible for the damages will arise, for the company whose carelessness caused the break is chartered under the laws of Mexico, while all the capital and all the stockholders are American. The break, furthermore, occurred in Mexican territory.

The Southern Pacific Railroad is making Herculean efforts to turn back the river, but the situation has become very desperate.



A SECTION OF THE IMPERIAL VALLEY WHICH WAS AT FIRST INUNDATED AND THEN LEFT HIGH AND DRY BY THE DEEPENING CHANNEL.

This photograph shows how the Southern Pacific Railroad tracks were cut into and washed out before the river found any channel or before the channel had cut any depth in the ground. Location, 6½ miles southeast of Calexico.—From the National Geographic Magazine.

THE NEW INLAND SEA.

THE PERMANENCE OF CONTINENTS.*

AMONG the early State geological surveys there were two commenced in 1836 which were destined to have in different ways a surpassing influence upon the development of geological thought. Those were the surveys of New York and Pennsylvania. In passing southwestward across New York, from the Adirondacks to the Pennsylvania border, one would traverse substantially the whole series of Paleozoic formations from the Cambrian to the Carboniferous, most of these formations extending across the State in approximately parallel east and west bands. That remarkably complete development of the Paleozoic series made the stratigraphy of New York a standard of comparison for the subsequent study of the Paleozoic strata throughout the eastern United States, as the stratigraphic series of England had already become, in its broader outlines, a standard of comparison for the world. But that regular succession of Paleozoic strata from the Adirondacks to the Pennsylvania border was suggestive of a dynamic idea. It suggested a gradual emergence of the land from the waters of the sea. In later years, as geological investigation extended westward, a somewhat similar succession could be traced in the Mississippi basin, southward from the Archæan mass north of the Great Lakes. The doctrine of the permanence of continent and ocean—the gradual emergence of continental lands and the withdrawal of the waters into the deepening ocean basins—was first enunciated by Dana in 1846. He had just returned from his voyage around the world in Wilkes's exploring expedition. In that voyage he had studied the phenomena of barrier reefs and atolls, had adopted Darwin's theory of their origin by subsidence, and had defended and illustrated the theory by a far greater wealth of observation than Darwin's route had afforded him the opportunity to make. It was, apparently, the thought of the subsiding ocean bottom, rather than the thought of the emerging land, by which Dana was first led to the doctrine of the permanence of continent and ocean; but, in his presidential address before the American Association for the Advancement of Science, in 1855, Dana refers to the stratigraphy of New York as illustrating the idea of continental emergence. The generation of students who have learned geology from Dana's "Manual" and "Text-Book," will remember how prominently he brings forward the succession of Paleozoic formations in New York, as illustrating his conception of the gradual emergence of the land from a continental sea.

The doctrine of the permanence of continents when announced by Dana was essentially a new one. Geologists and psuedo-geologists of all classes had felt at liberty to redistribute continents and oceans according to their own sweet will. After the biblical pseudo-geologists had become convinced of the impossibility of the deposition of the whole series of fossiliferous strata in the Noachian deluge, their next shift was the supposition that the fossiliferous strata had been deposited in the ocean in the interval between the creation and the deluge, and that at the time of the latter event continent and ocean were reversed. Hutton believed that the débris of the continents was carried far out to sea by means of ocean currents, and was deposited over substantially the whole floor of the ocean; and, when one continent was worn away, an-

* Abstract of a paper read by William North Rice before the American Association for the Advancement of Science.

other might be uplifted in some other part of the world. Lyell eliminated the catastrophe element of Hutton's theorizing; but, like his predecessor, Lyell believed in an indefinite amount of change in the distribution of continent and ocean. In attempting to find a geological explanation for changes of climate, he felt at liberty to speculate on a series of changes in the distribution of continent and ocean which would sometimes bunch the continents around the poles, and at other times girdle the earth with an equatorial belt of land. The readers of Darwin's "Letters" will remember his half comic, half pathetic protest, in a letter to Lyell, that the disciples of the great geologist "in a slow and creeping manner beat all the old catastrophists who ever lived."

There is now little doubt that Dana was right in his general conception. The greater density of the sub-oceanic masses in comparison with the sub-continental masses, as shown by pendulum observations, indicates that the distinction between continent and ocean has its basis in the heterogeneity of the material in the interior of the earth; and the determining conditions must, therefore, have had their origin in the initial aggregation of that part of the primitive nebula which formed the earth; or, perhaps, as suggested by Chamberlin and Salisbury, in changes attendant upon the beginning of the formation of the ocean. The study of the sedimentary rocks which cover our existing continents shows that almost all of them were deposited in shallow waters; many of the strata, indeed, in waters so shallow that the layers of mud and sand were from time to time exposed by the receding tide or the subsiding freshet, to dry and crack in the sun or to be pitted by raindrops. None of the sedimentary deposits seem to have been formed in waters of truly oceanic depth.

Certain it is, however, that Dana made the evolution of the continents too simple an affair. He recognized, indeed, that the progressive emergence of the continental lands was attended by continual oscillation; yet, even in the last edition of his "Manual," it appears that he did not duly appreciate the magnitude of those oscillations. We now know that in early Cambrian time the Mississippian sea was only a sound or strait, most of the area in which the Trenton limestone was subsequently deposited being then dry land. Only gradually did the Appalachian strait widen out into the Mississippian sea. A true conception of continental evolution must recognize two complementary truths: a wide range of oscillatory movement, and yet on the whole a progressive deepening of ocean basins and a progressive emergence of continental lands. Chamberlin has formulated the doctrine of an alternation of marine and continental periods due to an intermittently progressive deepening of the ocean basins, and has connected therewith an ingenious and beautiful theory of climatic changes in geological time.

The doctrine of the progressive evolution of continents, as taught by Dana, gave new clearness and emphasis to the general conception of geology as a history of the globe. Le Conte, in his cordial and generous eulogy of Dana, declared that "geology became one of the great departments of abstract science, with its own characteristic idea and its own distinctive method, under Dana." There is certainly somewhat of exaggeration in this commendation, yet the statement contains an important truth. More or less clearly, all geological investigators must have felt that the distinctive idea of geology is that the structures of the rocks of the earth's crust have their supreme significance as monumental inscriptions, the deciphering of which may reveal to us the history of the earth. Yet this conception was never before so clearly formulated, and the whole treatment of the subject so consistently adjusted thereto, as in the writings of Dana. The portion of previous manuals dealing with the local distribution of the series of strata had generally borne some such title as "Stratigraphical Geology"; and very commonly, as in the well-known works of Lyell and De la Beche, the series had been traced backward, beginning with the most recent strata. In Edward Hitchcock's "Elementary Geology," with which, in my boyhood, I commenced the study of the science, the stratigraphic chapter bears the title, "Lithological Characters of the Stratified Rocks." It occupies only twenty pages in a book of more than four hundred pages. It traces the formations backward in Lyellian fashion. Separate from the stratigraphic chapter, is another and longer chapter on paleontology, which is arranged botanically and zoologically, and not chronologically. The phrase, "Historical Geology," which forms the title of the largest section of Dana's "Manual," involves a distinct clarification of the general view of the science. Starting with this conception, he, of course, dealt with the earliest formations first. In the treatment of each era he endeavored to reconstruct, from the evidence afforded by the kinds and distribution of the rocks, the physical geography of the time. The subdivisions of that chapter of the "Manual" are characterized, not as series, systems and groups of strata, but as eras, periods and epochs of time. The common use, in recent geological writings, of such phrases as "Silurian era," rather than "Silurian system," etc., is a testimony to the influence of Dana's mode of treatment.

Plumbers' solder, or wiping solder as it is commonly called, is composed of 40 per cent tin and 60 per cent lead. It has the interesting and valuable feature that at certain temperatures it takes the form of a pliable mass, allowing it to be easily handled and molded to produce the characteristic form of plumber's wiped joint. This operation of wiping is briefly described by the Valve World as follows: "The parts to be joined are first freshly tinned at the points of contact, to remove the oxide, and then firmly placed and secured in position. The melted solder is poured on the parts for the purpose of heating them. As the parts become hot the solder becomes cool, taking on the pliable form above mentioned, and is easily manipulated by the mats in the hands of the mechanic, when the joining is completed." It might be added that the ability to make a wiped joint is the principal stock in trade of the average plumber as distinguished from a steam fitter, and that no good reason for maintaining this ancient method of making plumbing connections exists in general. There are a number of mechanical joints on the market which have the merit of cheapness, ease of application, and which can be readily disconnected in case of needed repairs. Needless to say, the plumbing fraternity have worked tooth and nail against the general adoption of this needful improvement.

THE CRUISER OF THE FUTURE.

It is being more fully realized than formerly that even the principles of strategy must vary or progress with the change of weapons. The enormous advantage of wireless telegraphy, if not also of torpedo and submarine craft, must influence the practice of war. For instance, as Mr. Julian Corbett pointed out in his lecture at the Royal United Service Institution, a close blockade has now become impossible, owing to the advent of these three important auxiliaries in naval warfare. In carrying out an open blockade or investment of a port so that the watching ships shall be beyond the range of torpedo action either from surface or submarine craft, it becomes necessary to have an exceptionally high speed. Only thus may full advantage be taken of geographical conditions—i. e., of temporary lairs, from whence to make a dash after the enemy in the event of his trying to escape. The size of the area within which such positions may be sought is in direct proportion to the speed. If strategy may thus be influenced by advances in connection with the improvements in *matériel*, tactics are likely to be more extensively affected, and this is particularly so in connection with cruisers. Wireless telegraphy has enormously increased the possible area within a screen formed by the scouts of a squadron. As a consequence, it is impossible to ascertain the full strength of an opposing squadron within such a screen without driving home a reconnaissance in force. This necessitates powerful cruisers, so that they may come within sight of the main force of the enemy without suffering. Accurate information must be got at all costs. Unless this risk can be taken, no admiral can be certain of the adequacy of his scouting force. The futility of depending on cruisers of deficient power, when the enemy may use as scouts the fastest of his well-gunned ships, is fully recognized. Vessels of the "Invincible" class have consequently been made the most powerful cruisers yet conceived so far as present knowledge goes.

Indeed, these vessels more closely resemble battleships than any cruiser yet built. Their armor is only excelled by the ships of the "King Edward" class and the "Dreadnought" class. Their armament is equaled in broadside fire, or in bow and stern fire, only by the vessels of the "Dreadnought" class. Their speed of 25 knots is immensely superior to that of any armored ship afloat. As regards coal capacity, they are equal to any cruiser in the service, carrying 1,000 tons on normal draft; and although the high power necessary to give the maximum speed will make severe demands on the fuel supply, the radius of action should be satisfactory. This is the element in design which is most likely to be criticised on the ground that speed has probably been bought at some cost in respect of endurance. This raises the interesting question as to whether speed or endurance is the preferable quality in cruisers. It has been a cardinal principle in British warship design that radius of action is of greater consequence to a British fleet than to a foreign fleet, but there is suggestion now of some tendency to modification of this view. For oversea work endurance is more essential, perhaps, than speed; but in the "narrow seas" speed is probably preferable. The number and distribution of our coaling-stations greatly simplifies the problem so far as our navy is concerned. On the other hand, the absence of such coaling stations intensifies the difficulties experienced by foreign powers. In the competitive game the more we can "force our rivals to sacrifice endurance to speed, the easier is our imperial defense." Herein lies the strategical dilemma of the foreign naval designer, the one which has involved serious delay in the laying down of ships to meet our "Dreadnoughts" and our "Invincibles."

The problem of the protection of merchant shipping may somewhat complicate the situation. The Admiralty view, which must be accepted as the result of careful analysis of war experience, and therefore most reliable, is that the most effective procedure is to engage the enemy before the dissipation of his forces for the attack of commerce. Such dissipation of force, however, would be exceedingly dangerous, because the influence of wireless telegraphy must soon result in the attacking ship being mastered by a cruiser squadron, presuming even that she could keep the seas without returning for supplies to ports more or less closely invested by our fleets. There are those, however, who consider that special commerce-protectors should be provided. Indeed, they contend in favor of the maintenance for the purpose of ships more or less obsolescent, and this view is based on the success of Japanese ships inferior to some of our vessels now regarded as practically obsolete. There is, as we have time and again pointed out, a danger of deducing lessons from the Russo-Japanese war which are not justified, owing to the ineptitude of the Russian ships, or the special conditions prevailing. To utilize experienced officers and men in slow or defectively-armed ships, which would be at the mercy of one modern high-speed cruiser with high velocity guns, seems to be courting disaster. The present trend is distinctly in favor of cruisers acting in squadrons in order to bring the enemy to fleet action, and to make it impossible, if not dangerous, to engage in a *guerre de course*. As Sir Charles Dilke pointed out at the London Chamber of Commerce on Wednesday evening, a neighboring naval power, after an inquiry by most competent authorities, had abandoned the view that it could, while not holding the seas against us, inflict great damage to our commerce.

The combination of qualities in the new cruisers has necessitated an exceptionally long ship. Hitherto the longest of the British modern cruisers have been the "Powerful" and "Terrible," and the four armored ships of the "Drake" class, all of which had a length of 500 feet and a beam of 71 feet. Following the "Drake" class, completed six years ago, there was a tendency to decrease the length of the vessels, but later there has been steady advance. Thus the "County" class are 440 feet, the "Devonshire" class 450 feet, the "Duke of Edinburghs" 480 feet, and the "Minotaurs" 490 feet. The beam has, in the same period, been increased from 66 feet to 74½ feet. The three "Invincible" cruisers are 530 feet long and 78 feet 6 inches beam, the draft continuing, as in most of the recent armored cruisers, at 26 feet. This increase in length of 30 feet, as compared with the longest preceding cruiser, and of 40 feet as compared with the immediate predecessor, is necessary partly to enable high speed to be realized with the minimum of power, as the form for a given displacement may be finer, but it is a consequence also of the need for satisfactory disposition of the guns. It was laid down as an essential condition, first, that all the guns of the primary battery should be of 12-inch caliber—a condition never before exacted in any ship except the "Dreadnought"—and, second, that all the guns should have an arc of training to enable them to fire on either broadside and through very large arcs forward and aft. Eight guns are mounted in pairs in barbettes, one forward and one aft, and one on each broadside, but not, as in previous ships, on the same transverse line, the port barbette being some distance forward of the starboard barbette. This constitutes, as we have already indicated, a broadside armament equal to that of any ship afloat, equal even to the "Dreadnought," and it will be interesting to show in tabular form the progress in the gun-power of successive armored cruisers.

BROADSIDE FIRE OF SUCCESSIVE ARMORED CRUISERS.

Class and Year of Launch.	Designed Speed.	Displacement.	Number and Caliber of Guns Firing on Each Broadside.	Collective Muzzle Energy from One Round.
	Knots.	Tons.		Foot-Tons.
County (1900)	23.00	9,800	Nine 6-in.	31,290
Drake (1901)	23.00	14,100	Two 9.2-in. Eight 6-in.	63,600
Devonshire (1904)	22.25	10,850	Three 7.5-in. Three 6 in.	40,400
Duke of Edinburgh (1904)	22.75	13,550	Four 9.2-in. Five 6-in.	99,500
Minotaur (1906)	23.00	14,600	Four 9.2-in. Five 7.5-in.	137,000
Invincible (1907)	25.00	17,250	Eight 12-in.	381,576

It will be seen that in seven years the displacement tonnage nearly doubled, and that the collective muzzle energy from one round of guns has increased more than twelvefold. What is of more importance, however, is that the "County" class are only capable of fighting at three miles' range, and even then against inferior ships. It is true that the "Drake" class of six years ago can effectively bring to bear two guns at four miles' range; the "Duke of Edinburgh" class and the "Minotaur" class, four guns of the same range; whereas the "Invincibles" will be able to utilize all of their eight guns at five miles' range, and then to do effective work against any foreign battleship. In this way they will be able to combat an equal number of battleships of the enemy's force while doing reconnaissance work, having at the same time a speed which will enable them, after gleaning all information as to the force of the enemy, to return to the admiral with full knowledge of the strength of his opposing force. Although their armor protection may not be as effective as the latest of our battleships, they will still be able to take their place in the line of battle; and on the principle that the most effective defense is an active and preponderating offense, they will do effective duty.

The value of the superior gun-power is further considerably augmented, not only by the unification of the caliber of the gun for reasons which were admirably enunciated by Lieutenant-Commander Sims in the report which we reproduced on page 59 *ante*, but because of the exceptionally high freeboard of the ships. In the preceding cruisers—notably the "Duke of Edinburgh" class and the "Minotaur"—the forward guns were placed on the forecastle, which was cut away on each side to enable the wing guns on the upper deck level to fire ahead. These wing guns, like all the other primary weapons in the ship, are in these earlier cruisers on the upper deck level. In the new ships the broadside guns are on the same level as the forecastle, and therefore at a great height above the water-line. The aft pair of guns alone are on the

upper deck level; but the deck erection to the rear of these stern guns is cut away at an acute angle on each side to enable the aft weapons to train as far as possible forward of the beam. The disposition of the guns and machinery has involved difficult problems in order to secure a wide arc of training, and as this is a matter of increasing importance in the design of warships, considerable interest will be taken in the paper to be read at the Institution of Naval Architects by Mr. James McKechnie, of Barrow-in-Furness, as his unique experience of both propelling and gun machinery entitles him to speak with authority on "the influence of machinery on the gun-power of the modern warship."

As to the armor protection, this, as in the earlier ships, is continued right fore and aft, and extends from a considerable distance below the water-line to the upper deck level, the gun machinery above this being further protected by the barbettes. The armor on the broadside amidships is, for some distance, 7 inches in thickness, reduced forward and aft to 4 inches, while all of the guns and the machinery are thus within heavy armor. Although the protection is not equal to that of the "Dreadnought," it corresponds with the plating of the "Duncan" class, with this further advantage, that it is continued right aft as well as forward. As suggestive of the relative extent of armor protection in modern cruisers, it may be added that the proportion of weight of hull to the displacement tonnage of the ship in the "County" class was 60 per cent, in the "Devonshire" class 61.5 per cent, in the "Duke of Edinburgh" class 59 per cent, in the "Minotaur" 56.3 per cent, and in the "Invincible" 56 per cent. The inference may be justified that the weight devoted to protection is relatively less than in the earlier ships; but the length of the ship is a factor in such comparison, and in any case the difference is small.

The machinery is of the Parsons type, with water-tube boilers designed to give 41,000 horse-power. The disposition of the machinery has been arranged to enable a magazine for the amidship guns to be placed under the guns, and there are three boiler compartments, with two engine compartments, the latter divided by a longitudinal bulkhead. The turbines are arranged as in the "Dreadnought." There are four shafts. On each of the center shafts there are fitted a cruising turbine and low-pressure ahead and astern turbines, the latter two being within one casing. On each of the wing shafts there are a high-pressure ahead and high-pressure astern turbine. At cruising speed, therefore, the sequence, going ahead, will be, the cruising turbine on the inner shaft, the high-pressure turbine on the outer shaft, and the low-pressure turbine on the inner shaft; while for going astern the sequence will be, the high-pressure turbine on the outer shaft, and a low-pressure turbine on the inner shaft. There are four propellers, one on each shaft, and the outer propellers are about 20 feet ahead of the inner. The two inner shafts are carried within spectacle framing and stern bracket, and are immediately ahead of the two rudders. These, as in the "Dreadnought," hang from the stern structure in a coned bearing, and they are further secured by nuts. These rudders are of very ample area, so that the turning power of the ship will be considerable.—Engineering.

ROENTGEN, CATHODE, AND POSITIVE RAYS.

IN his fourth lecture on the above subject, delivered at the Royal Institution, Prof. J. J. Thomson, F.R.S., said that the real nature of the cathode rays had, in the past, constituted almost an international question between German and English physicists. The idea that the discharge consisted of moving particles negatively electrified appeared, he continued, to have originated with Mr. Cromwell Varley, but the evidence that this was their nature had been more fully established by Sir William Crookes. In spite of the latter's experiments, however, Helmholtz was almost the only German physicist to accept the theory in question, the others following Goldstein in holding the contrary creed. This opposing view received a considerable impulse from experiments by Herz, who found that the discharge could pass through gold-leaf and aluminium-foil. At that date, which was much antecedent to the discovery of radium, this fact seemed to negative the view that the discharge consisted of moving electrified particles. Nowadays, the speaker continued, we had become accustomed to the penetration of solids by small particles, and quite recently Mr. Campbell Swinton had shown that ordinary hydrogen even could penetrate into glass to a greater depth than the thickness of the foils used by Herz. Still, when the latter's results were first published, the fact of penetration seemed irreconcilable with the view that the discharge consisted of negatively-electrified particles. The matter was further investigated by Leonard, in a very remarkable series of experiments, in which he obtained the discharge outside the vacuum tube by fitting the latter with a window of thin aluminium-foil. This experiment was repeated by Prof. Thomson, who showed that a screen coated with willemite became fluorescent when placed close up to the aluminium window, and also showed that on moving the screen back to a distance of but two millimeters from the window, the glow nearly disappeared, thus indicating that the discharge was very rapidly absorbed by air at the ordinary pressure. By letting the discharge pass through a vacuum after escaping from the aluminium window, a relatively long travel of the discharge was possible, and in these conditions it appeared that it could be deflected by a magnet; thus negativing the idea that the fluorescence of the willemite was caused by Roentgen rays generated by the impact of the discharge on the glass or metal window of the tube.

The fact that he was able to show these experiments in the lecture room was a striking testimony, the speaker continued, to the advantages conferred by Sir James Dewar's method of obtaining high vacua by the use of charcoal cooled to the temperature of liquid air. When Prof. Leonard brought over his apparatus to the British Association meeting at Liverpool, Sir Gabriel Stokes and himself, the speaker said, had spent hours with Leonard in endeavoring to get the effect in question; but at the end of that time they could not conscientiously say they had seen it. Considering the great difficulty of the experiment under the conditions in which Leonard worked, it was remarkable that he had failed to discover the Roentgen rays, which were much more easily detected.

The fact that the particles could get through sheets of metal raised the question as to what was the nature of these carriers of the electricity, and what was the velocity with which they moved. The latter could be determined, he continued, with the apparatus represented in Fig. 2 in our report of the previous lecture (see page 317 *ante*). Here the cathode rays were passed between two opposite electrified plates placed horizontally. If X denoted the strength of the electrostatic field between these plates, and e the charge on a particle, then the force tending to move it vertically was $X\,e$. If at the same time a magnetic field of strength H were established at right angles to the electrostatic field, and to the direction of motion of the particles, each particle would again be subject to a vertical force having the value $H\,e\,v$. By adjusting the two fields, matters could be arranged so that the two forces exactly balanced each other, and then it followed that $v = \dfrac{X}{H}$. The velocity thus determined came out enormously high; the figure obtained ranged, with the degree of exhaustion of the vacuum tube, from 6,000 miles per second to 60,000.

Again, by letting the force H act alone, the particle would be compelled to describe a curved path. It could be shown that if m was the mass of the particle, v its velocity, and e its charge, that the radius of the path described under the influence of H was given by the expression

$$\frac{v}{R} = \frac{He}{m}$$

from which as v, H, and R were all determinate, the ratio $\dfrac{e}{m}$ was obtained.

Thus calculated the ratio came out enormously high, being equal to 1.7×10^7. In electrolysis the ratio of charge to mass varied with the ion involved, being greatest for H, when it had the value 10^4 or 1/1700 that obtained in the case of the particles constituting the cathode rays. It then remained to discover whether the charge e was greater than it was in the case of H, or whether the mass m was smaller than that of the hydrogen atom. By a series of experiments, into which he said he would not enter, it had been shown that the charge was the same as that carried by the H atom in electrolysis, and hence the mass m was only 1/1700 that of this atom. An important point was that though many ways were now known of getting these particles, such as by heating metal till it became luminous, or by the action of violet light on metals, or from radio-active bodies, this mass was always the same. The smallness of this mass explained how it was that particles found their way through sheets of metal.

One consequence of the enormous velocity of these particles was that their kinetic energy might be large in spite of the smallness of the mass. The momentum on the other, depending only on the product $m\,v$, need not be so large. Hence in these particles, we found a large kinetic energy combined with a very small momentum. Take, he said, the case of a tube in which the velocity of the particles was 60,000 miles a second, and the current conveyed was 1/1000 of a milliampere, which was about the normal intensity. Then, the kinetic energy of one particle would be $\dfrac{m\,v^2}{2}$, and if n particles passed in unit time, the total energy would be $\dfrac{n\,m\,v^2}{2}$. The charge carried by each being e, the current i was equal to $n\,e$, so that the energy became $\dfrac{i\,m\,v^2}{2\,e}$. The ratio $\dfrac{e}{m}$ being 1.7×10^{-7}, it appeared, on making the necessary substitutions, that for the tube in question the point at which the particles struck the glass received energy at the rate of about 4 calories per minute. As the rays could be concentrated, a very high temperature could be developed at the point struck, and, as Sir William Crookes had shown, a diamond could be fused in this way. In the case of the momentum, however, there was a very different story to tell. Assuming that the particles rebounded with undiminished velocity on striking the glass, the change in the momentum due to the collision of the particles would be $2\,m\,n\,v$. On substituting as before, it appeared that the pressure exerted by them if they struck a square centimeter of the glass could not exceed 1/10,000 of one-millionth of an atmosphere.

It was obvious, therefore, he went on, that the particles could have no direct mechanical effect. Sir William Crookes had, however, shown that if directed on the vanes of a wheel running with its axle on guides in the vacuum tube, this wheel could be propelled from one end of the tube to the other. The calculation just made showed that the pressure exerted by the stream was incompetent to do this, and, in fact, the apparent mechanical effect arose indirectly, and was due to the heating of the sides of the vanes struck by the particles. Starke, by a very pretty experiment, had definitely shown that this heating was the cause of the effect observed. He suspended from a fiber a disk with its plane horizontal, and directed the rays obliquely against one side of the lower surface of the disk. Had the rays a direct mechanical effect they should, under these conditions, cause the plate to twist about its suspension; but an indirect effect, due to the heating of the lower surface of the disk, would simply tilt it. No indications of a twisting effect were found by this observer.

The use of the cathode rays as an indicator for magnetic forces was, the speaker proceeded, coming more and more into use. They had no period of their own, and practically no inertia, so that they could follow the most rapidly-changing magnetic forces. He had himself tried to use them for the detection of the electric waves used in wireless telegraphy. The magnetic field of these waves was very strong, but was reversed very rapidly. With the usual system of transmission, however, he had failed to get good results, owing to the fact that the waves used were so discontinuous. As a consequence, the deflection of the cathode rays by the magnetic field of the waves lasted for less than 1/1000 the total time of the signal, and could not, therefore, be detected. With Poulsen's system, in which a continuous train of waves was employed, this difficulty would not arise, and he believed the rays would show a deflection, even if the waves alternated one million times per second.

A very neat method of studying the properties of the rays had been introduced by Kauffman, who received them on a photographic plate. The apparatus was arranged so that the rays passed through a magnetic and an electrostatic field, the respective displacements due to each being at right angles to each other. The displacement due to the electrostatic field varied inversely as the inertia of the particle, and that due to the magnetic field inversely as the momentum. If, therefore, the rays, when the fields were shut off, made a spot on the plate, they would, if all had the same velocity, still make a spot on the plate when displaced by the simultaneous action of the two fields. Actually they had not all the same velocities, and as a consequence the original spot became a curve, by the study of which the character of the discharge could be determined.—Engineering.

ESTIMATES OF POPULATION, 1904, 1905, 1906.

UNITED States Census Bulletin 71, just published, presents the population returns for 1905 of the fourteen States making an interdecennial enumeration, together with the estimated population of these States for 1904 and 1906, and of the remaining States and Territories for 1904, 1905, and 1906.

The States which took a census in 1905 are Florida, Iowa, Kansas, Massachusetts, Minnesota, New Jersey, New York, North Dakota, Oregon, Rhode Island, South Dakota, Wisconsin, and Wyoming. In Michigan the census is taken in the years ending with a "4." The population returns for these States was 26,263,877, an increase since 1900 of 1,901,572, or 7.8 per cent. For the remaining States and Territories the population for 1905, as determined by the method of estimating adopted by the Bureau of the Census, was 56,283,059, an increase over 1900 of 4,374,040, or 8.4 per cent. The population of the fourteen States making an enumeration, if estimated in the same manner, would be 26,204,762, a difference of only 0.2 per cent from the actual returns. This close approximation is evidence that in all cases where the results of an enumeration are not available, the estimates may be accepted as the best attainable substitute.

The population of continental United States in 1905, as obtained by adding to the returns of the States which took a census in that year the estimated population of the remaining States and Territories, is 82,574,195, an increase over 1900 of 6,579,620, or 8.7 per cent.

The estimated population for continental United States for 1906 is 83,941,510, and for the United States, inclusive of Alaska and the insular possessions, 93,182,240. Computed on the basis of the estimate, the density of population of continental United States in 1906 is 28 persons per square mile, as compared with 26 in 1900. The States having a density in 1906 exceeding 100 per square mile, exclusive of the District of Columbia, with amount of increase for 1900 and 1906, are as follows:

State.	1906	1900	Increase.
Rhode Island	460	407	53
Massachusetts	379	349	30
New Jersey	292	250	42
Connecticut	209	188	21
New York	173	153	20
Pennsylvania	155	140	15
Maryland	128	121	7
Ohio	109	102	7

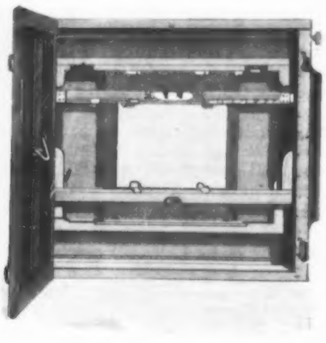
The rapid growth of urban population is noteworthy. The total estimated population of municipal-

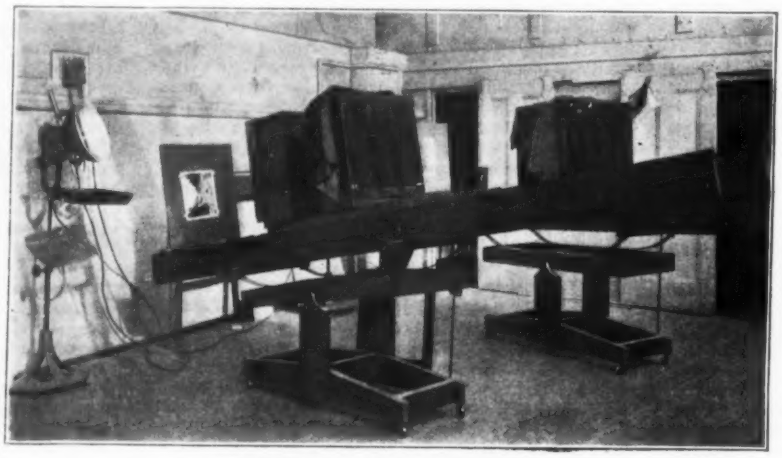
ities—that is, incorporated places having 8,000 or more inhabitants—exclusive of San Francisco and Los Angeles, Cal., is 28,466,624 for 1906, an increase over 1900 of 3,912,188, or 15.9 per cent, while the estimated population of the United States, exclusive of these cities, showed an increase of 4,480,008, or only 8.8 per cent.

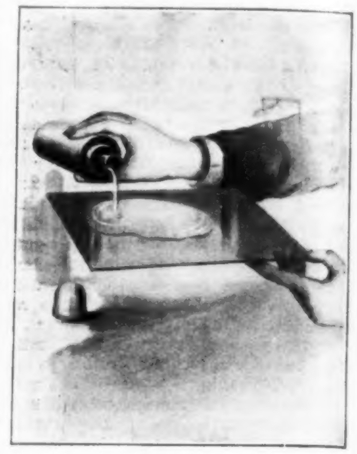
The 88 cities with an estimated population of 50,000 or more in 1906 had a total estimated population of 19,771,167, an increase of 2,766,863, or 16.3 per cent, over that reported at the Twelfth Census. Cities which have come into this class in the period from 1900 to 1906 are Norfolk, Va.; Yonkers, N. Y.; Schenectady, N. Y.; Houston, Tex.; Tacoma, Wash.; Terre Haute, Ind.; Dallas, Tex.; Youngstown, Ohio; Fort Wayne, Ind.; Holyoke, Mass.; and Akron, Ohio. The five leading cities and their estimated population in 1906 are as follows: New York, 4,113,043; Chicago, 2,049,185; Philadelphia, 1,441,735; St. Louis, 649,320, and Boston, 602,278.

THE MAKING OF A HALF-TONE ENGRAVING.

The general introduction of photo-mechanical engraving processes has wrought a revolution in the publishing world. Possibly it has not been as far-reaching as regards books as in the case of periodicals, but it has changed entirely the character of many magazines and weekly papers, and now it is possible even for daily papers to make half-tone plates which are adapted for printing on octuple presses in a space of time

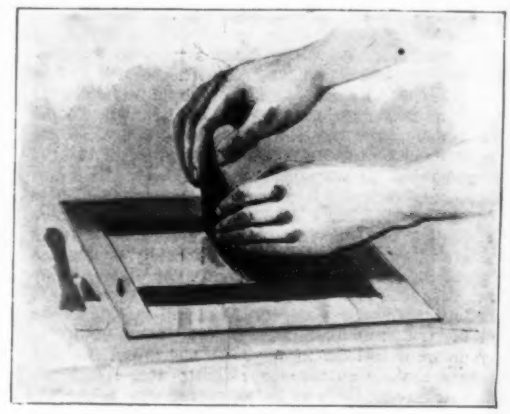

THE PLATE HOLDER.


THE PHOTOGRAPH GALLERY.

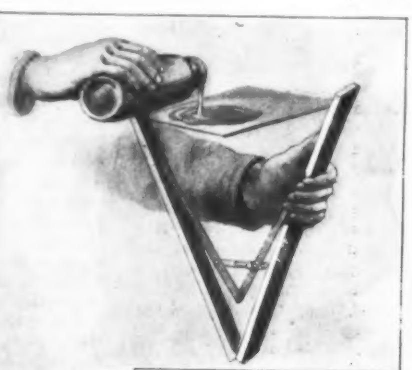

FLOWING WITH COLLODION.


PRINTING WITH THE ELECTRIC LIGHT.

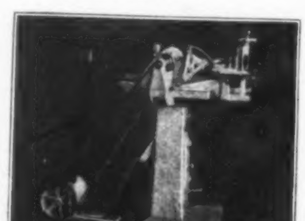

SQUARING THE FILM.


STRIPPING THE FILM.


WHIRLING THE SENSITIZED COPPER PLATE


COATING THE COPPER.


FINISHING THE PLATES.


BEVELING MACHINE.


ROUTING THE PLATES.


FINISHING AND PROVING PLATES.

THE MAKING OF A HALF-TONE ENGRAVING.

which a few years ago would have seemed nothing less than marvelous. The new processes have permitted of double and treble the number of illustrations being used, owing to their comparative cheapness. As for

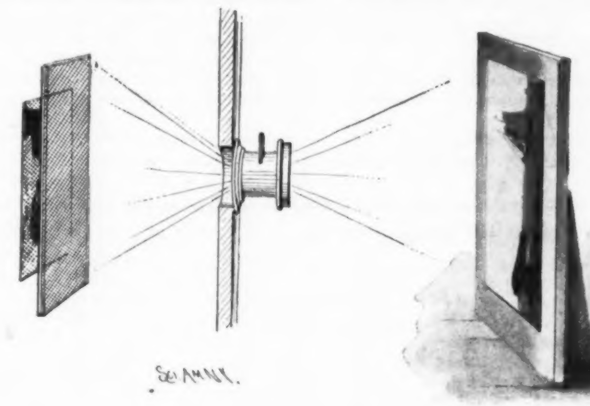


DIAGRAM SHOWING THE RELATIVE POSITION OF PLATE, SCREEN AND COPY.

the quality of the work, it is safe to say that these processes should be used to the exclusion of all others for reproducing works of art and certain classes of subjects in which the interposition of artists or artist-artisans is not desirable.

The very general adoption of the half-tone process for the illustration of high-class periodicals and books practically sounded the death-knell to wood-engraving, which is fast becoming almost a lost art, having comparatively few exponents of note at the present writing, so that in a few years wood-engraving will be practised, perhaps, only in art schools.

Omitting an historical outline of the steps by which the half-tone process has been developed, we will proceed at once to describe a thoroughly modern process establishment, taking up the various steps in the making of a half-tone plate, from the time the copy is placed before the camera until a reproduction of it is printed in the periodical. The plant which we have selected for the purpose of illustration is located on the fourteenth floor of a building devoted almost entirely to printing, and being next to the Brooklyn Bridge the building enjoys remarkable advantages as to light. When the copy, which is usually a photograph or a wash drawing, is brought into the establishment, the requirements of the customer as to time of delivery, character of plate, fineness of screen, proofs, etc., are entered upon numbered cards, which are temporarily filed away (to later receive data as to size of plate and cost of making), the operative data on the cards being noted upon slips which follow the plates through the various stages of manipulation in the shop. If the photograph needs retouching it is sent to the retouching room, where several artists are employed. The retouching of photographs is practically a new profession, and the results which are obtained by this treatment are very remarkable. On a machinery subject it is possible for the retouching to exceed in cost five or ten times the expense of making the plate.

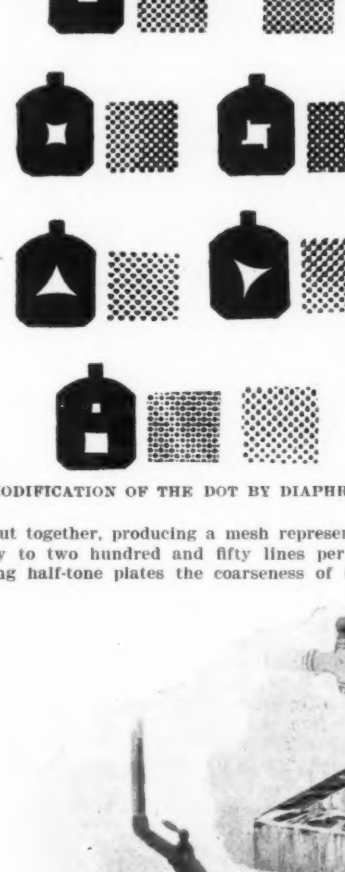
The copy is taken up to the photographic gallery, where both daylight and electric light through powerful arc focusing lamps are available, the latter being used chiefly on cloudy days.

The first step in the production of the half-tone plate is the making of the half-tone negative, which differs from the ordinary dry-plate negative in that the half-tone image is recorded in the shape of a series of dots and spaces due to the use of a finely-ruled glass screen. The camera beds are made very long in order to obtain the proper reduction in cases where the copy is large and the desired plate small. The copy is fastened to the copy board, which stands vertically at right angles to the runway at one end of the camera bed, the latter being adjustably supported by springs attached to the stand proper, the object of the springs being to absorb vibration, or, to put it in another way, to insure the simultaneous vibration of the camera box and copy, so that the relation of one to the other is absolutely the same throughout the time of exposure.

Having moved the camera box back and forth along the bed until the image is of the desired size, the camera box is then firmly secured to the bed by a turn of a binding screw and the image is brought into sharp focus on the ground glass. The photographer is now ready to prepare his wet-plate, the wet-plate process being particularly adapted for photo-engraving purposes, owing to the facility with which it can be manipulated to get desired results. He takes a perfectly clean piece of glass, previously albumenized, free from dust, and flows over it an iodized collodion, obtaining an even coating by allowing the collodion to run off at one corner of the glass plate.

When the collodion sets, the plate is then sensitized by placing it in a silver nitrate bath. When sensitized the plate is put in the plate-holder and is then ready for the exposure. The process plate-holder is of special construction and is adjustable so as to hold any size plate up to the limit for which the camera was designed. The holder also contains the ruled screen which is placed at a very short distance from the sensitized plate, between the latter and the lens, as indicated in the accompanying diagram. This diagram also serves in a measure to show how the production of the dots of the half-tone negative is effected.

The half-tone screen is made up of two plates of glass that have been carefully ruled on one side, the plates being cemented together, ruled side to ruled side, in such a way that while the lines are ruled diagonally across each plate, the lines of one plate run at right angles to those on the other when the two plates



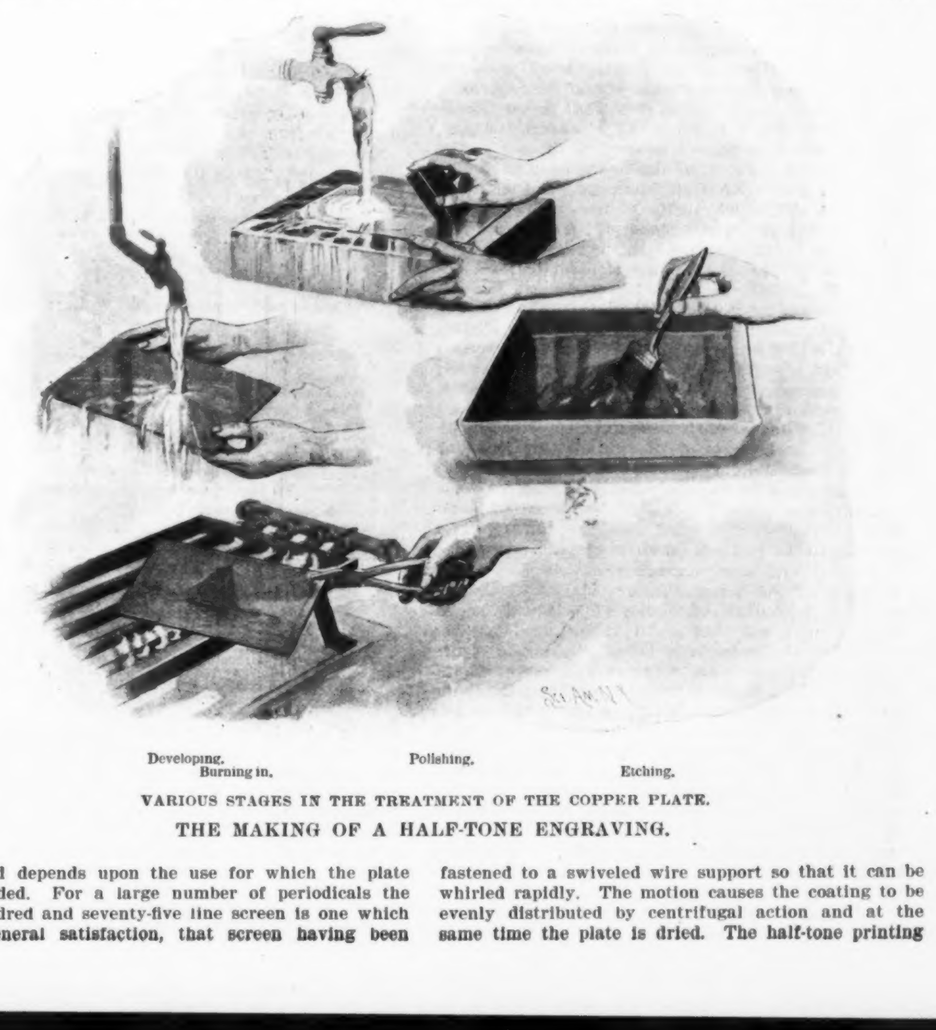
MODIFICATION OF THE DOT BY DIAPHRAGMS.

are put together, producing a mesh representing from eighty to two hundred and fifty lines per inch. In making half-tone plates the coarseness of the screen employed depends upon the use for which the plate is intended. For a large number of periodicals the one hundred and seventy-five line screen is one which gives general satisfaction, that screen having been used in making the engravings which accompany this article.

The dot in the half-tone negative represents the double effect of the screen and the diaphragm, which is inserted in the tube of the lens. The forms of some of the diaphragms are jealously guarded by photo-engravers. Square and round-hole diaphragms as well as many other types are employed, as shown in our diagram, the kind of diaphragm used depending upon the effect desired in the negative. When the print from the half-tone block is examined, it will be found that the size of the dots and spaces varies, the dots being smallest in the high lights of the picture, growing larger in the dark portions, the inter-spaces growing correspondingly small, and disappearing entirely in the absolutely black parts of the picture. The form of the dot can also be modified by the use of different intensifiers. The first diaphragm to be used having been inserted in the lens-tube, the plate-holder having been secured in place and its slide drawn, the cap is removed from the lens and the exposure begins, the time of the exposure depending upon the character of the copy, intensity of light, effect to be secured, etc. At night or when daylight is not sufficiently strong, electric light is used.

Having been exposed, the plate is taken to the dark room and developed, the kind of developer used depending upon the judgment or particular practice of the operator, the expert varying his manipulation with different subjects within surprisingly wide limits. The image appears in about five seconds, and the plate is fixed with a solution of potassium cyanide. If the negative is not of the required density, it is intensified. The negative is allowed to dry, when it is coated with a solution of rubber, and this coating is followed by another of collodion for the purpose of securing greater body in the negative to permit of its being handled. In order to secure a printed image like the copy it is necessary to reverse the negative. Should the negative not be reversed then the right hand side of the printed proof would represent the left hand side of the photographic copy. This is done by stripping the film from the plate. The glass is placed in a specially designed "squaring frame" having squared metal edges, and after adjusting the T-square and squaring the negative, as shown in one of our engravings, the portion of the film which it is desired to transfer for printing is cut with a sharp knife, so that when placed in an acid bath for the purpose of loosening it from the glass the desired portion may be readily removed, reversed, and transferred to another and thicker glass plate, which is used in printing the picture on the sensitized copper.

The copper plates come already polished, but it is necessary to give them a high finish before using. This is accomplished by rubbing them with willow charcoal and water. The copper plate is dried and coated with a sensitizing solution, which is flowed on in the same way as the collodion was on the glass plate. The copper plate is placed in an A-shaped clamp and the sensitized coating is evenly distributed over the plate by means of what is called the "whirler," the construction of which will be readily understood by reference to the engraving. The clamped plate is hung face downward toward the floor in a large box having a gas stove at the bottom, and is fastened to a swiveled wire support so that it can be whirled rapidly. The motion causes the coating to be evenly distributed by centrifugal action and at the same time the plate is dried. The half-tone printing



Developing. Burning in. Polishing. Etching.

VARIOUS STAGES IN THE TREATMENT OF THE COPPER PLATE.

THE MAKING OF A HALF-TONE ENGRAVING.

frame does not differ materially from the ordinary photographic printing frame, except that it is much more strongly built and is heavier. In the front of the printing frame there is a sheet of plate glass about an inch thick. The negative is placed in the printing frame next to the front glass with the face of the negative in contact with the sensitized copper plate. The back of the printing frame is then secured and by means of a number of hand screws great pressure is applied so as to hold the copper plate in the closest possible contact with the negative. Either daylight or electric light can be used for printing. One of our engravings shows the latter method, the required exposure with electric light taking more time than with daylight. When the plate is taken out it is placed under a jet of running water, by which means the image is developed. Following development, the copper plate is gripped with a pair of pliers and held over a gas stove, as indicated by one of our illustrations, for the purpose of "burning in" the image, after which process the plate is placed in an etching bath of chloride of iron, wherein it receives the first etch. What are termed flat proofs of the plate are then made on a "Washington" hand proving press, and if the flat proof indicates the presence of those qualities in the plate that have been sought, the plate then passes to the "router."

In the case of a vignetted subject, where the tint is allowed to die away around the edges, the plate is clamped in what is called a "routing" machine which is designed to give a speed of three or four thousand revolutions per minute to a small cutter whose section is varied according to the part of the work it is intended to perform. The routing machine, like all the other machinery of this establishment, is run by an independent electric motor. The router follows around the edges of the tint, cutting away all superfluous metal. Except in the case of silhouettes, there is little routing in subjects which are not vignetted, but in some cases the sky or background of a picture which is defective is removed by the router. In the case of what are known as "square" plates, a bevel groove is run all around the plate at a short distance from the printing edge to allow for securing it to the wooden block on which it is to be mounted, and also to permit of the excess metal being readily cut off.

If an examination be made of most half-tone plates, it will be found that there is a black line bounding them with a white line just inside the black one. Both lines, together with the grooving, are made on the plate by a beveling machine, which is something like a planer and a milling machine combined. The plate is securely clamped to a movable bed, which is moved by hand, planer fashion, so as to bring the plate under a steel graver, which cuts the black line and the white line in the plate. The current is then turned on to the motor, causing a circular beveling cutter to rotate at a high rate of speed. The bed carrying the copper plate is then run under the cutter, which "mills" a groove. This is done with all four sides of the half-tone.

The plate is now ready for the "finishers," upon whose artistic judgment much of the success of the plate depends. The finishers "stop out" or paint out with asphaltum varnish those parts of the engraving which are not to be re-etched. In the accompanying illustration of the finishing operation, the workman on the right is engaged in painting out the locomotive, to the smallest detail, so that the background may be lightened by re-etching. The finishers take out all imperfections in the plate, improving it as compared with the original copy by means of roulettes, burnishers, and wood engravers' tools. The extreme high lights are often put in with the engravers' tools, a sample of which work will be seen in the cut of the grooving and scoring (technically styled "beveling") machine, in which the high lights are emphasized by white lines. The high lights of the picture having been re-etched, and the shadows burnished where necessary, in order to secure brilliancy without a sacrifice of the delicate middle tones, a proof of the plate thus "finished" is inspected and passed upon, the full quota of proofs are "pulled," and then the plate is ready for mounting or "blocking." Holes are drilled for the nails that are to secure the plate to the wooden block, which is cut to the proper size, the excess metal being cut away before blocking. Nothing but the best seasoned maple, especially prepared, is used for blocking. Such, in brief, are the many and complicated steps necessary to make a satisfactory half-tone plate. It needs not only a considerable plant, but also expert and conscientious work at every step of the process. We are indebted to The American Machinist Press, whose photo-engraving plant we illustrate, for courtesies in the preparation of this article.

In view of the general interest taken in the approaching apparition of Halley's periodical comet, Messrs. Cowell and Crommelin have undertaken the computation of the perturbations. Wishing to obtain a preliminary survey as to the correctness of Pontécoulant's perihelion date, they have made a computation of the Jupiter perturbations, dividing the comet's orbit into eighty portions, and following Pontécoulant's method closely. The two main results of this inquiry are: (1) May, 1910, is the correct date within a month for the next perihelion passage. Their actual date is a fortnight earlier than Pontécoulant's, but no stress is laid on this difference. (2) Pontécoulant's value of the eccentricity for 1910 is notably in error, the perihelion distance being practically the same as at the last return (0.59), whereas he increased it to 0.68. This change is of importance, as it would considerably affect the geocentric path of the comet at the next return, and would considerably modify the point at which the meteors accompanying the comet would intersect the earth's orbit.

THE CHEMICAL COMPOSITION OF TOOL STEEL.*

THE MORE IMPORTANT CHARACTERISTICS OF HIGH-SPEED TOOLS.

THE best tool steel should be capable of producing high-speed tools of the following qualities or characteristics:

a. Tools should be of such composition that comparatively small errors of imperfections in the heat treatment will not seriously injure them and thus render them irregular in their cutting speeds. That is, the steel should be of that composition from which it is easy to make uniform tools.

b. Tools should not fire crack easily from the heat treatment.

c. Tools should be capable of running at the highest standard speed in cutting either hard, medium, or soft steel; or hard, medium, or soft cast iron.

d. Tools should be difficult to ruin on the grindstone or through overheating in the lathe.

e. Tools should be tough in the body—i.e., not liable to break in use even when receiving severe jars or blows from the work.

f. Tools should be capable of taking fine feeds in cutting hard metals with proportionally high cutting speeds, as when taking coarse feeds.

g. Tools should be easy to dress or shape without requiring very high heat.

h. When injured through use in the lathe, the quality of the tool steel should be such that the injury can be repaired by grinding off as small an amount as practicable from the tool.

No tool steel has yet been developed which possesses all these qualities in the highest degree. It is, however, a most interesting and useful fact that the tool steel marked No. 1 in the accompanying Table I. possesses all except two of these qualities in as high a degree as any steel that we have tested. The two defects possessed by this steel are that it is rather difficult to forge into a tool, and although it is very tough in its body, it is not as tough as tools whose bodies are either annealed or partially annealed.

In this table we give the chemical composition of various makes of tool steel now in use, and we believe that this list contains the most noted and, as far as we know, the best English, German, and American brands of high-speed tool steels. Opposite each make of tool will be found its standard speed, 20 minutes' duration, 3-16 inch depth of cut, 1-16 inch feed, in cutting:

a. Medium tool steel, about 0.34 per cent carbon, 73,000 pounds tensile strength, 30 per cent stretch.

b. Very hard annealed tool steel, about 1 per cent carbon, 100,000 pounds tensile strength, 6 per cent stretch.

c. Very hard cast iron.

It has been our experience that a tool capable of cutting metal of these three qualities at high speeds is also capable of cutting at correspondingly high speeds almost any other quality of steel or cast iron which is softer than those given. Tools are sometimes found which will cut the very hard metals at high speeds, and yet not do proportionately well on the medium metals; but if they cut both the very hard and the medium, our experience is that they are equally good for anything softer. Many tools can be found, however, which cut softer metals well and yet fall down badly in cutting hard steel or hard cast iron.

We are just completing (October 20, 1906) a series of tests with the tools upon the forgings and castings just referred to. In addition to this we have tested in cutting the same pieces of metal the old-fashioned carbon tools of the Jessop make; two Mushet tools, one used by us in our former experiments and the other an especially fine quality of Mushet tool dating back to the early nineties; also tools used by us in our experiments for developing the Taylor-White process, which resulted in high-speed tools. In addition to these, we have also tested upon the same forgings and castings some of the tools used by us since the Bethlehem experiments in determining the laws for cutting metals, and some of the tools used by us in experiments made since the Bethlehem experiments to determine the chemical composition of those high-speed tools which at that time ranked first.

By referring to the table, it will be noted that, while No. 1 tool is in all respects better than any of the others, yet the differences in cutting speeds are comparatively small between this tool and several of those following it. Therefore the users of tool steel cannot go far wrong by adopting any one of these noted brands of tool steel, but having once adopted a make of tool steel we would strongly advise against changing,

Table I.—Chemical Compositions and Cutting Speeds of the Best High Speed Tools.

Including noted English, German and American makes experimented upon by us in the summer and fall of 1906.

Number of the tool steel	Year in which analysis was made.	Vanadium. Va.	Molybdenum. Mo.	Tungsten. W.	Chromium. Cr.	Carbon. C.	Manganese. Mn.	Silicon. Si.	Phosphorus. P.	Sulphur. S.	Medium steel forging.	Hard steel forging.	Hard cast iron.
1	1906	0.32	....	17.81	5.95	0.682	0.07	0.049	.....	.....	90 ft.*	41 ft. 6 in.	52 ft.
		0,29	....	18.19	5.47	0.674	0.11	0.043	.....	.....			
2	1906	....	....	16.19	3.86	0.736	0.06	0.210	.....	.....	91 ft.*	40 ft.	50 ft.
3	1906	....	....	14.41	3.28	0.709	0.07	0.120	.....	.....	......	39 ft.‡	50 ft.
4	1906	....	....	17.61	4.24	0.502	0.10	0.240	.....	.....	......	38 ft.‡	49 ft.
5	1906	....	....	14.23	3.44	0.739	0.06	0.165	.....	.....	......	39 ft. 6 in.	46 ft.
6	1906	....	....	25.45	2.23	0.838	0.29	0.034	.....	.....	......	39 ft.	47 ft.
7	1906	....	....	14.91	5.71	0.790	0.06	0.060	.....	.....	......	38 ft. 6 in.	47 ft.
8	1903	....	0.48	17.79	2.84	0.650	0.12	0.087	0.013	0.012	70 ft.†	37 ft.	45 ft. 6 in.
9	1903	....	....	19.64	2.85	0.760	0.30	0.090	.....	.....	......	37 ft.†	45 ft. 6 in.†
10	1903	....	....	18.99	2.61	0.670	0.20	0.265	0.014	0.009	......	37 ft.†	45 ft. 6 in.†
11	1903	....	....	23.28	2.80	0.800	0.11	0.165	0.015	0.009	......	37 ft.†	45 ft. 6 in.†
12	1903	....	2.03	18.93	3.52	0.580	0.19	0.125	0.029	0.016	......	37 ft.†	45 ft. 6 in.†
13	....	....	4.21	13.44	3.04	0.760	0.09	0.052	.....	.....	......	37 ft.†	45 ft. 6 in.†
14	1905	....	....	24.64	7.02	0.600	0.03	0.205	.....	.....	85 ft.*	38 ft.†	44 ft.
15	1906	....	....	19.97	3.88	1.28	0.14	0.220	.....	.....	84 ft.*	38 ft.*	....
16	1906	....	....	19.16	5.61	0.79	low.	low.	.....	.....	85 ft.*	37 ft.*	....
17	1906	....	7.60	9.25	6.11	0.32	0.13	0.081	.....	.....	86 ft.*	37 ft.*	....
18	1906	0.28	....	16.00	3.50	0.70	low.	low.	.....	.....	......	38 ft.*	....
19	1906	....	....	16.00	3.50	0.70	low.	low.	.....	.....	......	34 ft.*	....
20	1903	....	....	14.71	2.90	0.700	0.12	0.196	0.017	0.010	64 ft.	34 ft.	44 ft.
21	1903	....	....	15.31	2.88	0.540	0.12	0.133	0.018	0.009	......	34 ft.†	44 ft.†
22	1902	....	0.75	14.91	2.80	0.450	0.10	0.090	0.018	0.008	......	34 ft.‡	44 ft.†
23	1903	....	....	14.62	2.81	0.600	0.18	0.323	0.017	0.009	......	....	....
24	....	....	6.25	.....	4.30	0.900	0.12	0.481	0.016	0.008	......	....	....
25	....	....	....	10.68	3.67	1.160	0.10	1.340	0.024	0.008	......	....	....

* Tools marked thus were actually run in 1906 upon a 0.43 carbon forging which has a standard cutting speed as 48 : 60 compared to the cutting speed of the 0.34 carbon referred to in this column.

† Tools marked thus were run on another forging or casting and the cutting speeds given were judged by comparing the qualities of the two forgings or castings and the speeds of the other tools run at the same time.

‡ Tools marked thus were not run a sufficient number of times in this particular case to be certain of the correct speeds. The figures given are therefore partly estimated.

Both analyses of No. 1 make tools of practically the same cutting speed, forging hard at light cherry red. Should be forged at a light yellow, but at which heat it forges more readily than the old self-hardening steel. This is the best high speed steel with which we have experimented.

Nos. 2 to 23 are rather hard to forge.

Cutting speeds of Nos. 23 to 25 are inferior to any of the others.

Table II.—Chemical Composition and Cutting Speeds of Various Self-Hardening and Carbon Tools Experimented with by Us Prior to Our Discovery of High Speed Tools.

	Number of the tool steel.	Year in which analysis was made.	Molybdenum. Mo.	Tungsten. W.	Chromium. Cr.	Carbon. C.	Manganese. Mn.	Silicon. Si.	Phosphorus. P.	Sulphur. S.	Medium steel forging, standard speed, not treated at a high heat.	Hard steel forging.	Very soft cast iron.
Mushet	65	1898	....	5.62	0.490	2.40	1.90	0.711	0.055	0.051	26 ft.	....	.....
Atha and Illingsworth (self-hardening)	66	1898	4.58	......	3.430	1.615	1.65	0.285	0.027	0.016	24 ft.	....	.....
Firth Stirling Company	67	1898	....	7.57	0.600	2.300	3.22	0.269	0.019	0.007	24 ft.	....	.....
Midvale Steel Company	68	1898	....	8.48	1.460	1.386	0.32	0.358	0.016	0.022	30 ft.	....	.....
Sanderson S. H.	33	....	....	6.83	3.940	1.470	0.37	0.770	.....	.....	....	....	.....
Sanderson	60	1896	....	4.48	3.955	1.512	0.31	0.233	0.017	0.023	27 ft.	....	.....
Midvale (self-hardening)	70	1894	....	7.723	1.830	1.143	0.18	0.246	0.023	0.008	25 ft. 8 in.	10 ft. 11 in.	89 ft.
Mushet (self-hardening)	71	1894	....	5.441	0.398	2.150	1.578	1.044	.....	.....	25 ft.	7 ft. 9 in.	86 ft.
Sanderson (self-hardening)	72	1894	....	4.537	2.410	1.400	0.324	0.216	0.018	0.006	24 ft. 10 in.	8 ft.	81 ft.
Jonas & Colver (self-hardening)	73	1894	....	10.721	2.958	1.850	2.325	1.027	.....	.....	21 ft. 6 in.	6 ft. 10 in.	.....
Burgess special (self-hardening)	74	1894	....	7.599	0.074	2.320	3.530	0.630	0.036	0.004	....	....	.....
Mushet air hardening, Pennsylvania Steel Company	75	1893	....	6.057	0.342	2.213	1.800	0.883	0.037	0.023	....	....	.....
Stirling Steel Company (self-hardening)	76	1893	....	8.387	0.254	1.806	1.870	0.156	0.018	0.008	....	....	.....
Sanderson (self-hardening)	77	1893	....	7.506	1.464	1.690	2.590	1.024	0.088	.....	....	....	.....
Sanderson (self-hardening)	78	1893	....	7.368	0.200	2.178	2.500	0.162	0.016	.....	....	....	.....
Sanderson (self-hardening)	79	1893	....	11.589	2.094	1.842	2.430	0.890	0.023	0.007	....	....	.....
Imperial (self-hardening), Park Bros., Pittsburgh	80	1893	....	6.923	0.675	1.732	2.520	0.250	0.019	0.014	....	....	.....
Sanderson (self-hardening)	81	1893	....	7.975	1.325	1.625	2.670	0.976	0.072	0.011	....	....	.....

* From "The Art of Cutting Metals," read by Fred W. Taylor, Philadelphia, before the American Society of Mechanical Engineers.

and particularly against allowing any other steel to be used in the same shop.

CARBON TOOL STEELS.

[A study of the relations between the chemical composition of various tool steels and their cutting speeds is given in a table which we omit, showing that, as to carbon tool steels, but small differences exist in the cutting speeds of the various makes; in fact, when cutting the same quality of metal the cutting speeds do not vary more than 6 per cent.—THE EDITOR.]

Some of these analyses include several tools which are not self-hardening, and yet contain tungsten or chromium, which must be hardened or tempered in the old-fashioned way to be of any use; and yet to these steels have been added the two metals which when combined in sufficient quantities produce self-hardening tools. A study of the chemical compositions of these steels is chiefly interesting for two reasons:

1. Because they illustrate the fact that the presence of tungsten even to the extent of 7 per cent produces a tool which has no more self-hardening properties than ordinary carbon steel, the reason for this being that there is but an exceeding small amount of either manganese or chromium present; and also that a tool may contain 1.6 per cent of chromium, an ample percentage to make good self-hardening steel if either tungsten or molybdenum were present and still have no self-hardening properties.

2. Because they show clearly that the addition of 1.6 per cent of chromium, coupled with 0.71 per cent of carbon (a very low carbon for a tempered tool steel) and also with 0.10 per cent manganese (a decidedly low manganese for a tempered tool steel), gives the tool a materially higher cutting speed than that of the ordinary carbon tempered tools.

We made a very exhaustive examination of this steel, but the fact that it required more skill on the part of the blacksmith in judging its proper hardening heat than the ordinary carbon tools prevented its adoption as a standard shop tool, even although tools of this composition could be run at a cutting speed materially higher than the carbon tempered tools. When a steel, either carbon, self-hardening or of the modern high-speed tool variety, shows any marked tendency to fire crack or toward brittleness we promptly abandon all idea of its adoption as standard.

Table II. gives the analyses of several self-hardening tools made between the dates of 1893 and 1898, and of these Nos. 65, 66, 67, 68 and 33 were experimented with by us at the Bethlehem Steel Company just prior to the discovery of the Taylor-White process while searching for the best self-hardening steel to adopt as a shop standard for that company. Many other brands of self-hardening tools had been tested previously by us as to their cutting speeds, but because of evident inferiority to the above brands were not analyzed or tested at this time. These five makes of tool steel, then, are interesting because they represent, so far as we know, the best self-hardening steels then in the market, and the only makes which we believed to be worthy the expenditure of time and money required in making careful standard speed tests on the experimental lathe. It is notable that two steels out of the five (Mushet and Firth-Stirling) depended for their self-hardening properties upon a comparatively large percentage of manganese in combination with tungsten, while three of them depended mainly upon high chromium in combination with tungsten or molybdenum. It will be observed that No. 68 (Midvale) gave the highest cutting speed, but this steel was seriously injured in the operation of heating by the blacksmith, which injury led to the discovery of the Taylor-White process. It is highly likely, therefore, that had not the high-speed tools been discovered the Mushet self-hardening steel No. 68 would have been adopted by us as our standard in spite of the slightly higher cutting speed of the Midvale steel, since the Mushet steel gave evidence of overheating by the blacksmith through crumbling when hammered. Thus the Mushet tools, when injured by overheating, remained in the blacksmith shop, while overheated Midvale tools were likely to get into the machine shop and interfere seriously with the uniformity in the shop tools.

Table III.—The Chemical Compositions and Cutting Speeds of Various Tools Used by Us in the Discovery and Development of the Taylor-White Process for Making High Speed Tools by Heating Tools Close to the Melting Point.

	Number of the tool steel.	Molybdenum. Mo.	Tungsten. W.	Chromium. Cr.	Carbon. C.	Manganese. Mn.	Silicon. Si.	Medium steel forging. Standard speed old style not treated T-W process. Ft.	In.	Medium steel forging. Standard speed treated T-W process. Ft.	In.	Very hard steel forging treated T-W process. Ft.	In.	Hard cast iron treated T-W process. Ft.	
Recommended in patent for cutting hard steel	26	....	8.00	3.80	1.85	0.30	0.150	27		58		35	6	43	
Recommended in patent for cutting medium and soft metals	27	....	8.50	2.00	1.85	0.15	0.150	31		61		19		39	
	28	....	8.76	1.75	1.30	0.39	0.395	32	6	61	5				
Better tools made during development of Taylor-White process	29	....	8.38	1.62	1.26	0.31	0.432	..		60					
	30	....	....	2.01	.....	...	.....	..		60					
	31	....	7.89	2.16	0.858	0.47	0.288	..		61					
	32	....	6.50	2.77	1.860	1.19	0.379	32		61	3				
	33	....	6.83	3.94	1.470	0.37	0.770	27		61	3				
	34	....	7.68	3.78	1.810	0.32	0.191	20	11	57					
	35	....	7.94	3.81	1.950	0.41	0.572	..		59*					
Recommended in patent for cutting hard steel	26	....	8.00	3.80	1.85	0.30	0.150	27		58					
Effect of high chromium	34	....	7.68	3.78	1.81	0.32	0.191	20	11	57					
	35	....	7.94	3.81	1.95	0.41	0.572	..		59*					
	33	....	6.83	3.94	1.47	0.37	0.770	27		61	3				
Effect of low chromium	36	....	5.48	0.290	2.02	2.25	0.274	25	6	39	3				
	37	....	7.22	0.467	2.40	3.26	0.249	26	10	37	9				
	38	....	7.57	0.600	2.30	3.22	0.269	27	5	37					
	39	....	7.18	0.670	2.40	3.44	0.270	20 / 21		39 / 36	10 / 11				
	40	....	8.58	0.720	0.977	0.39	0.231	20		50					
Effect of low tungsten	41	....	0.83	3.80	1.80	2.19	....	27		23					
	42	....	1.91	3.25	1.87	0.56	....	37		45					
	43	1.77	....	1.64	0.89	0.50	....	45†		58					
	44	0.84	....	2.01	1.02	0.53	....	27		35					
For effect of high tungsten see almost all other analyses.															
Recommended in patent for cutting hard steel	26	....	8.00	3.80	1.85	0.30	0.15	27		58					
Effect of high carbon	35	....	7.94	3.81	1.95	0.41	0.572	..		59*					
	45	....	7.94	1.45	2.44	2.91	0.908	..		56*					Hard to forge.
	46	....	8.05	2.61	2.27	0.42	0.792	..		57*					
	32	....	6.50	2.77	1.86	1.19	0.379	32		61	3				
Effect of low carbon	31	....	7.89	2.16	0.858	0.47	0.288	..		61					
	40	....	8.58	0.72	0.977	0.39	0.231	20		50					
	47	....	7.87	1.00	1.200	0.41	0.291	30		50					
	29	....	8.38	1.62	1.260	0.31	0.432	..		60					
	48	....	3.55	1.91	1.290	0.42	0.235	23	8	47	2				
	28	....	8.76	1.75	1.300	0.39	0.395	32	6	61	5				
Effect of high manganese	45	....	7.94	1.45	2.44	2.91	0.908	..		56*					Hard to forge.
	49	....	8.61	1.40	1.14	2.38	0.980	22	6	..					
Effect of low manganese	50	4.20	....	3.95	1.18	0.08	....	..		60					Irregular.
	51	....	8.15	1.91	1.68	0.12	0.16	32	6	55					
	52	....	8.85	1.75	1.54	0.13	0.09	..		..					
	53	....	8.41	3.29	1.54	0.24	0.32	25		50	6				
	54	3.67	....	3.86	1.84	0.30	0.23	27	6	60					Irregular.
	34	....	7.68	3.78	1.81	0.32	0.191	20	11	57					
	33	....	6.83	3.94	1.47	0.37	0.770	27		61	3				
Molybdenum substituted for tungsten	55	0.56	....	.....	1.05	0.20	0.120	16	10	..					
	56	0.84	....	2.01	1.02	0.53	....	27		35					
	57	0.94	....	.....	1.07	0.20	0.15	21	10	..					
	43	1.77	....	1.64	0.89	0.50	....	45†		58					
	58	2.03	4.53	2.08	2.02	1.69	0.282	31 / 36		58 / 58	4 / 4				Tendency to fire crack.
	59	2.25	4.74	2.80	2.07	1.66	0.120	36		58	4				Tendency to fire crack.
	60	2.45	....	3.19	1.22	0.66	0.240	30		50					
	54	3.67	....	3.86	1.84	0.30	0.230	27	6	60					Irregular.
	50	4.20	....	3.95	1.18	0.08	....	..		60					Irregular.
	61	4.58	....	3.43	1.61	1.65	0.285	....		59					Brittle in body and fire cracks easily.
	62	4.59	....	3.46	1.51	1.62	0.245	45	3	..					Brittle in body and fire cracks easily.
	63	4.60	....	3.75	1.84	1.79	0.156	45		..					Brittle in body and fire cracks easily.
To test annealing qualities	51	....	8.15	1.91	1.68	0.12	0.16	32	6	55					Annealed readily.
	52	....	8.85	1.75	1.54	0.13	0.09	..		..					Annealed readily.

* The record of their cutting speeds could not be found. Speeds given from memory.

† Tools run on another forging or casting and the cutting speeds given were judged by comparing the qualities of the two forgings or castings and the speeds of other tools run at the same time.

No. 26 is considerably harder to forge than No. 27, just below.

No. 27 is easy to forge.

No. 28 was one of the lot of tools used in the first series of experiments which led to the discovery of the Taylor-White process.

The chemical composition of the forgings and castings above used was as follows: Medium steel forging—Carbon 0.34, manganese 0.54, silicon 1.76, phosphorus 0.037, sulphur 0.026. Hard steel forging—Carbon 1.00, manganese 1.11, silicon 0.305, phosphorus 0.036, sulphur 0.049. Hard cast iron—Carbon total 3.32, combined carbon 1.12, manganese 0.68, silicon 0.86, phosphorus 0.78, sulphur 0.073.

ANALYSES AND CUTTING SPEEDS OF VARIOUS TOOLS EXPERIMENTED WITH BY TAYLOR AND WHITE IN THE DISCOVERY AND DEVELOPMENT OF THE NEW HIGH-SPEED TOOLS.

Table III. gives the chemical compositions of various steels experimented with by us during the time of the discovery and development of the new high-speed tools by Mr. White and the writer. These tools are separated into various groups for the purpose of showing the relative effect of comparatively large and small quantities of each of the following elements upon the cutting speed—namely, tungsten, molybdenum, chromium, carbon, and manganese.

After the columns giving the percentages of the various ingredients of which the tools are composed two columns are found, in the first of which is entered the cutting speed of the steel when given the ordinary heat treatment as practised before our invention, and as in many cases recommended and even superintended by the makers of the tool steel. In the second column are entered the speeds obtained by the same tools after having been treated carefully by the Taylor-White process of heating the tool close to the melting point, cooling it, and then reheating it to about 1,150 deg. F.

A study of the various groups of tools, together with their cutting speeds before and after receiving the high-heat treatment, will make clear the basis of our claim in patent No. 668,269, that tools containing one-half of 1 per cent or more of chromium and 1 per cent or more of tungsten, or its equivalent in molybdenum, are materially improved in cutting speed through the treatment by the Taylor-White process. This, however, is of minor interest. A subject of greater interest is the effect of the various elements when used in such quantities in the tool steel as to produce tools of the highest cutting speeds—that is, the highest degree of red hardness when treated by the Taylor-White process.

THE EFFECT UPON HIGH-SPEED TOOLS, AS ORIGINALLY DEVELOPED, OF TUNGSTEN, CHROMIUM, CARBON, MOLYBDENUM, MANGANESE, AND SILICON.

By examining the chemical compositions of the tools given after Nos. 26 to 35—namely, the groups of tools which after receiving the Taylor-White treatment gave the highest cutting speeds during the period of our invention—it will be noted, 1, that no tool in this group contains less than 6½ per cent of tungsten, and that the highest tungsten in this group is 8.76 per cent; 2, that no tool in this group contains less than 1.62 per cent of chromium, and that the highest chromium is 3.94 per cent. It would seem, therefore (as a result of these investigations), that to produce what we considered at that time first-class tools the chromium and tungsten must be within these limits.

The effect of low tungsten will be seen by examining tools Nos. 41 to 44. In No. 42 it will be noted that with 1.91 per cent of tungsten and 3.25 per cent of chromium a tool was produced which improved materially upon being heated to a high heat, whereas tool No. 41, containing 0.83 per cent of tungsten and 3.80 per cent of chromium, deteriorated materially in its cutting speed upon receiving the high-heat treatment. From this it is evident that even with high chromium more than 0.83 per cent of tungsten is required in the tool before the property of red hardness begins to be apparent, and also that high chromium tools are injured in their cutting speeds when overheated, although, of course, not to the same extent as ordinary carbon tools.

On the other hand, upon examining the carbon column, we note that the lowest carbon which produced a first-class tool was 0.858 per cent, while the highest carbon was 1.950 per cent. Between these limits, then, our experiments indicated that, as far as the effect of cutting speed was concerned, it was a matter of indifference whether low or high carbon was used. And it is a notable fact that many of the best high-speed tools developed up to the present date contain carbon in almost the same percentage as that indicated by the low limit in our experiments.

At the time that we were developing our invention it was not usual to make self-hardening steel containing carbon in as small quantities as 0.86 per cent. An increase of carbon produces an increase in the hardness of a self-hardening tool, although, as indicated by the group of tools from No. 26 to No. 32, increasing carbon beyond 0.86 per cent does not produce a higher cutting speed or a greater degree of red hardness, which is the distinctive quality of high-speed tools. We had the 0.86 per cent carbon steel made especially for the purpose of testing the effect of low carbon upon red hardness in Taylor-White treated tools. And it was the statement made in our patent, that high-heat treated tools containing 0.86 per cent of carbon gave as high cutting speeds as those containing high percentages of carbon, which first turned the attention of makers of tool steel in this direction.

Our adoption of the higher limits of carbon at the time of the writing of the Taylor-White patent was upon the supposition that through heating the tool many times in succession to the high heat, the carbon lying in the outer layers of the nose of the tool might be considerably reduced, and that with high carbon this reduction of carbon would leave the tool as efficient as ever, whereas with carbon as low as 0.86 per cent any material reduction in carbon might affect its cutting speed.

However, more recent experiments have shown that even with comparatively low carbon there is little danger of injuring the tool so that it cannot be repeatedly heated to the high heat from oxidization or burning out of the carbon in the outer layers of the tool; and in the best of the present high-speed tools the rather low carbon of 0.68 per cent is used for the purpose of rendering the steel more readily forged to the proper shape, and also to make it rather less brittle in the body of the tool.

Referring to the manganese column, it is notable that the lowest manganese is 0.15 per cent and the highest 1.19 per cent. It is clear, then, that low manganese does not affect the property of red hardness in high-speed tools. Low manganese renders the tool stronger in its body, less liable to brittleness, less liable to fire crack, and more easily forged and annealed; and for this reason we recommended a steel low in manganese as best for the Taylor-White treated tools.

By examining the three groups of analyses—namely,

the effect of high chromium and the effect of low chromium, and the effect of low manganese—it will be noted that making a tool of high chromium with the proper amount of tungsten invariably produces a high-speed tool, even although the manganese is low; but that a tool without chromium or with very low chromium, even though there is a proper percentage of tungsten present, does not produce a high-speed tool, even though the manganese may be low or very high. From this it follows that chromium is the element which in combination with tungsten produces the new quality of red hardness and not manganese.

(To be continued.)

THE MAKING OF SMALL INDUCTION COILS WITH BARE WIRE.*

By A. Frederick Collins.

In winding small induction coils, that is, those giving sparks up to and including two inches in length, the secondary may be formed of bare copper wire wound in layers on the primary helix instead of using insulated wire, which is usually recommended.

If the method of winding here described is followed a very efficient instrument will result, and what is equally to the point, the cost will be greatly reduced, since bare wire of the size required is only one-fifth as expensive as the same size of cotton-covered wire.

The sizes of wire and of parts given in the following tables are for one-half, one, and two-inch coils, those giving a shorter spark than half an inch being, in the opinion of the writer, of very little service, while on the other hand it is not deemed advisable to build coils giving a longer spark length than two inches either with bare wire or with continuous windings.

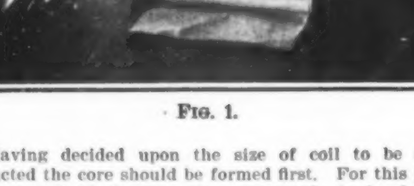


Fig. 1.

Having decided upon the size of coil to be constructed the core should be formed first. For this purpose a soft black iron wire, procurable in hardware stores in rolls, is probably the best that can be obtained without special effort; the exact diameter of the wire is of little consequence, and No. 20 Brown & Sharpe (American) gage, or wire a little larger or smaller, may be employed. The diameter and the length of the core are given in the following table:

TABLE I.

Spark Length of Coil.	Diameter of Core.	Length of Core.
½ inch.	½ inch.	5⅛ inches.
1 inch.	⅞ inch.	7¼ inches.
2 inches.	1¼ inches.	10½ inches.

The wire, after being cut and straightened, must be made into a compact and cylindrical bundle and forced into a stout paper tube a trifle longer than the core. By coaxing and carefully manipulating the wires it will be found possible to force a number of extra ones into the tube after the latter is apparently full, and a little sperm oil put on them will greatly facilitate this task.

The tube may be made of heavy manila paper cut into strips of the required width, while a cylindrical form may be obtained by rolling it on a turned piece of wood having the proper diameter; the process of forming the tube is shown in Fig. 1. As the paper is wound around the wood it should be glued at intervals to make it strong, and when this operation is completed it may be further improved by giving it a coat of paraffin or shellac. When perfectly dry, the tube will be hard, not easily bent out of shape, nor will it be affected to any appreciable extent by moisture. By referring to Table II. the inside diameter and length of a tube for a coil of given size may be ascertained,

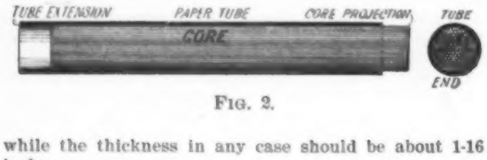


Fig. 2.

while the thickness in any case should be about 1-16 inch.

TABLE II.

Spark Length of Coil.	Inside Diameter of Tube.	Length of Tube.
½ inch.	½ inch.	5¼ inches.
1 inch.	⅞ inch.	6¼ inches.
2 inches.	1¼ inches.	10 11-16 inches.

It will be observed that the length of the soft iron wire core and the length of the paper tube differ to some extent, and a glance at Fig. 2 shows that one of the poles of the core—the end that passes through one of the cheeks of the coil and is to be used in connection with the vibrating spring interrupter—projects beyond one end of the tube, while the opposite end of the latter extends beyond the other end of the core—this serving as a support for the opposite cheek and providing means for finishing it neatly. Table III. indicates the proportions of these extensions.

* Specially prepared for the Scientific American Supplement.

TABLE III.

Spark Length of Coil.	Projection of Core from End of Tube.	Projection of Tube from Opposite End of Tube.
½ inch.	5-16 inch.	7-16 inch.
1 inch.	½ inch.	⅝ inch.
2 inches.	⅝ inch.	¾ inch.

The cheeks for the ends of the coil are disks of wood and may be varnished, or japanned to look

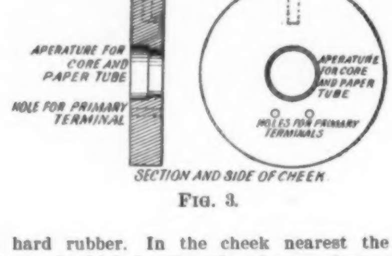


Fig. 3.

like hard rubber. In the cheek nearest the interrupter, and which for the sake of convenience may be designated as the front cheek, a hole is bored through its center just large enough to admit the end of the core projecting from the paper tube. For two-thirds the distance from the inside of the cheek the hole is bored out a trifle larger so that this portion will fit snugly over the end of the tube. A side and rear elevation of the right-hand cheek is shown in Fig. 3, the dotted circles indicating how the diameter of the aperture is enlarged for this purpose. Through the front cheek two small holes are bored near the aperture for the core, the ends of the primary coil leading out through them. The cheeks are completed by drilling a hole radially in each, that is, from its circumference through to its center, and a hole drilled from the inside at a point where the first layer of the secondary will come, to meet it, as shown in the dotted lines in Fig. 3. The sizes of the cheeks may be ascertained from the following table:

TABLE IV.

Spark Length of Coil.	Diameter of Cheeks.	Thickness of Cheeks.	Diameter of Holes for Primary Coil Terminals.
½ inch.	2⅝ inches.	⅜ inch.	⅛ inch.
1 inch.	3¾ inches.	⅝ inch.	3-16 inch.
2 inches.	4⅝ inches.	¾ inch.	¼ inch.

Before the cheeks are mounted on the core and tube the ends must be well smeared with a good adhesive

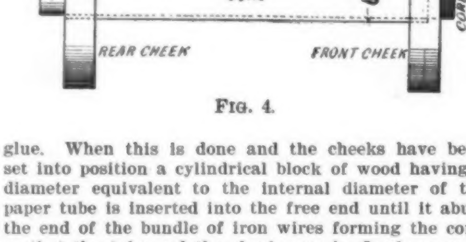


Fig. 4.

glue. When this is done and the cheeks have been set into position a cylindrical block of wood having a diameter equivalent to the internal diameter of the paper tube is inserted into the free end until it abuts the end of the bundle of iron wires forming the core, so that the tube and the cheek may be firmly secured to each other. The spool is now completed, except that it must be laid away to dry, and presents the appearance shown in Fig. 4.

When the spool is thoroughly dry, it is mounted in a lathe, the projecting pole of the core being placed in the chuck, while the wooden end receives the point of the back center. The kind of wire best adapted for the primary of an induction coil is that sold under the trade name of magnet wire, as this is much purer than that known as annunciator, bell, or office wire. The wire should be double cotton covered for the primary helix, the sizes required being obtainable from Table V.

TABLE V.

Spark Length of Coil.	No. of Wire (B. & S. Gage).	No. of Feet Required.
½ inch.	16	..
1 inch.	14	..
2 inches.	14	..

One end of the primary wire is passed through one of the holes of the front cheek from the inside, and all being in readiness, the mandrel is revolved slowly by a winch if the lathe is equipped with one, or if not then it will have to be turned by the belt. The turns of wire are wound closely together and tightly on the paper tube of the core clear up to the inside surface of the opposite cheek. When the layer is wound it is given a coat of shellac, and the second layer—only two layers are necessary for the primary coil—is wound back on top of the first. When the cheek where the winding was begun is reached, the wire is cut off, leaving the ends projecting through the holes about four inches. This layer is also shellacked and then a paper insulation is put on to keep the secondary current from breaking through and disrupting the insulation of the primary coil.

The insulation may be formed of good manila paper, and this is cut in strips having a width equal to the distance between the opposing surfaces of the cheeks. It should be coated with melted paraffin or with shellac and should be wrapped around the primary coil evenly and with care, so that when finished it will present a smooth and uniformly cylindrical surface upon which the first layer of the secondary coil can be wound directly. The succeeding table gives the width of the paper and the thickness of the insulation when the paper is applied.

TABLE VI.

Spark Length of Coil.	Width of Paper.	Thickness of Insulation.
½ inch.	4½ inches.	1-16 inch.
1 inch.	5¾ inches.	¼ inch.
2 inches.	9⅝ inches.	3-16 inch.

The exact amount of wire required for the secondary coil in order to produce a given length of spark is a difficult matter to predetermine by calculation, but some makers advocate the use of a mile of wire for every inch of spark length desired, while others suggest that about a pound of wire per inch of spark length is about the right amount. By experience, the size and amount of bare wire required for the different sized coils will be found in Table VII. as well as the number of turns per lineal inch.

TABLE VII.

Spark Length of Coil.	Size of Wire (B. & S. Gage).	Amount of Bare Wire Required.	Number of Turns to Lineal Inch.
½ inch.	No. 40	½ pound.	32
1 inch.	No. 40	¾ pound.	24
2 inches.	No. 38	1¾ pounds.	16

In winding the secondary coil with bare wire, the

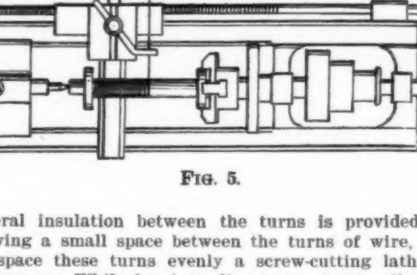


Fig. 5.

lateral insulation between the turns is provided by leaving a small space between the turns of wire, and to space these turns evenly a screw-cutting lathe is necessary. While few intending to construct coils will probably possess such a lathe, it is a part of the equipment of every gunsmith and locksmith in cities, towns, and villages, and he would be indeed an unworthy smith who would not permit his lathe to be used for so worthy a purpose.

The slide rest should be set at the number of threads per inch given in the last column of the preceding table and a guide fastened in the tool holder of the slide rest through which the wire leads from the spool on which it is purchased to the inductor spool in the lathe, as shown in Fig. 5. The end of the wire may be brought through the radial hole in the cheek to the outside, where it will form one of the terminals, and for the time plugged in with a bit of wood.

The mandrel is then turned, and as the slide rest moves toward the back center the wire will be wound on as evenly as the threads cut on a screw, and if a little tension is applied to the wire before it passes through the guide it will be wound on quite tightly. As the winding progresses it should be treated with shellac applied with a brush; this serves not only to insulate it but to hold it in place. When the layer has been wound to within half an inch of the surface of the cheek it should be examined closely to see that the turns have been properly spaced, for if any two adjacent turns touch each other the coil will be short-circuited.

On completing the first layer of wire, a sheet of

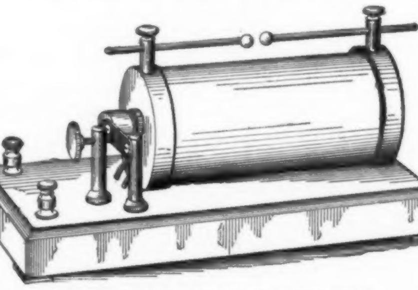


Fig. 6.—THE COIL COMPLETE.

calendered or other good paper free from pinholes and other defects is wrapped tightly on and coated with shellac or paraffin; the movement of the slide rest is then reversed and the next layer of wire—which is never broken—is wound on. It is the sheets of paper separating the successive layers of wire that insulate them from each other. The processes of winding the layers of wire and wrapping the sheets of paper around them are repeated until the spool has been wound with the requisite amount of wire. When the last layer has been put on, the end of the wire is brought out of the radial hole in the opposite cheek of the spool.

The diameter of the coil when the winding has been concluded will depend upon the thickness of the paper

used for insulating the adjacent layers of wire from each other, but in the ½-inch coil it should come to within ¼ inch of the circumference of the cheek, in the 1-inch coil to within 3-16 inch, and in the 2-inch coil to within ¼ inch. If there are not enough layers of wire and paper to give it the proper diameter, then it may be built up with additional sheets of paper.

The coil may be finished by bending a thin sheet of hard rubber, having a number of opposing holes drilled through near the ends and ¼ inch apart around it, and lacing it up with waxed black linen thread, or a cheaper way is to cover it with black pebbled book-binders' cloth and gluing the edges together.

The coil may then be taken out of the lathe and the cylindrical block removed from the aperture of the rear cheek and the shank of a turned button inserted in its stead to give it a finished appearance. The cheeks of the spool may then be screwed on the base of the instrument, which has previously been prepared to receive it, and which is provided with a condenser mounted in its interior, while a simple spring interrupter, reversing switch, and binding posts for connecting in the battery, are mounted on top.

When the terminals of the primary coil are properly connected with the foregoing devices, and each of the terminals of the secondary coil is connected with a brass plug end, to which it should be soldered, and then inserted in the radial hole, so that when the binding posts are screwed in they will make contact with them, the coil is complete and will present the aspect illustrated in Fig. 6.

PUMPING DEVICES FOR OPEN TANK SERVICE.*

By W. H. WAKEMAN.

IN thousands of buildings of various kinds and different heights it is necessary to maintain one or more tanks on the roof or in the upper story for the purpose of holding water to supplement the local department in case of fire, or for various uses in every-day service in and about the buildings. The expense of buying water from the water company, the lack of sufficient pressure in the mains to deliver this water where it is wanted in high buildings, or a combination of the two reasons given, makes it necessary in many cases to elevate it from wells, brooks, or street mains into these tanks by means of suitable pumps.

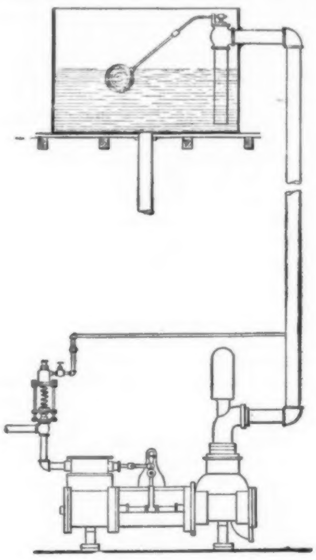


FIG. 1.

As the amount of water drawn out of these tanks from time to time varies greatly, and inasmuch as it is advisable to keep them nearly full without causing them to overflow, some kind of an automatic device is necessary to control the delivery of water that will be reliable in service and require little attention from the engineer in charge.

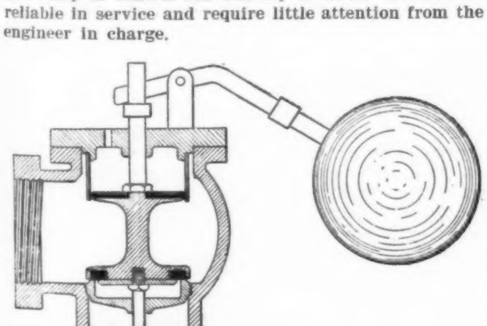


FIG. 2.

Fig. 1 represents an ordinary steam pump fitted with one of these devices. It is pumping water into an open tank, and near the end of the discharge-pipe there is a float-valve which shuts off the supply when the tank is full. Closing this valve causes pressure to rise in the discharge-pipe, and as there is a small pipe connected into it, this pressure is communicated to the regulator on the steam pipe, which is adjusted to close at a pressure slightly above normal conditions, thus shutting off steam and stopping the pump. When the water level in this tank is lowered a few inches, the float-valve opens, lowering the pressure,

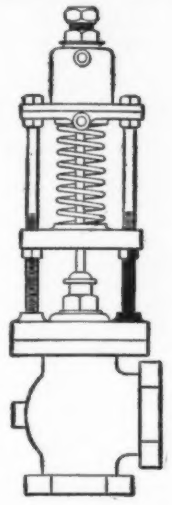


FIG. 3.

which permits the regulator-valve to open and admit steam to the pump again, thus securing water to maintain the desired quantity. These tanks should always be painted with Dixon's graphite paint to prevent rust and corrosion if made of iron, and to preserve the wood where tanks are made of this material.

An ordinary unbalanced float-valve will not answer for this service, as it will work so hard that much force will be required to close it, and when the water level falls it will not open easily with full pressure acting on it. Fig. 2 illustrates a balanced valve that overcomes these objectionable features, as it is so nearly balanced that but little force is required to close it, and for the same reason it opens easily. It must be connected so that water will enter at the side and be discharged through the bottom.

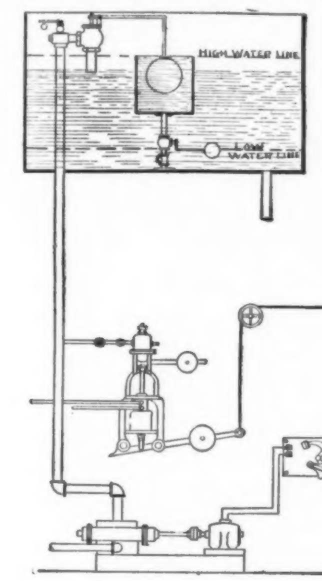


FIG. 4.

Fig. 3 illustrates a reducing valve or regulator, which may be used in the steam pipe of a pump to control its speed. With ordinary pressure in the discharge water pipe, the helical spring (more commonly but incorrectly called a coil spring), keeps the steam valve open, but when closure of the float-valve causes pressure to rise in the discharge water pipe it acts on a diaphragm in the regulator, and overcoming the spring closes the valve.

In cases where the pump is to be shut down for a long time without attention from the engineer, a special fixture may be required, but the foregoing description explains the principle of operation.

Poor cylinder oil is sometimes used to lubricate the cylinders of pumps that are fitted with these economical and useful devices, and as this oil goes through the regulators also, they soon become so clogged with sediment from the oil that they are absolutely useless, which is certainly a great mistake. It would be much better to use Dixon's flake graphite and eliminate the objectionable oil entirely.

Fig. 4 illustrates a pump driven by an electric motor operated by a controller to maintain a water supply in an elevated tank. The illustration shows the tank just after it has been filled, and the motor is now at rest. Water is being drawn out for use in the building below, thus lowering the water line, but the pump is not started because the small auxiliary tank remains full, and this holds the float up, keeping the discharge valve closed.

When enough has been drawn out to bring it down to the low-water line, the lower float-valve will open and quickly empty the small tank, thus lowering the large float and opening the discharge valve. As this at once lowers the water pressure, the reduction is communicated to the controller, its position is reversed, causing the large round weight to descend, drawing the small wire cable over the two pulleys shown, which throws the switch in and starts the motor, thus filling the tank again.

The first effect of putting in more water is to close the lower float, but nothing else happens until the high-water line is reached, when water flows over into the small tank, raises the float, which closes the discharge or float-valve in the water pipe and stops the pump by causing the controller to throw out the switch, thus bringing it again into the position shown.

The object of this is to prevent the motor from being started and stopped often, as it would be if only one float-valve was used to control the pumping system. A small safety-valve is shown at the top of the discharge water pipe, so that if the motor fails to stop on account of derangement of the connecting devices, the safety-valve will open and prevent excessive pressure in the pipe. Attention is called to the fact that there are no wires connecting the float with the motor, as only those from the dynamo, or the street service wires, to the motor are used in connection with this ingenious device.

In buildings where an engine is run every day it is often advisable to utilize power from this source for pumping water, or in other words to run a power pump. In order to do this satisfactorily it is necessary to have a pump large enough and give it sufficient speed to supply the maximum quantity desired. An arrangement for shutting it down when the tank is full should form part of the outfit, as otherwise it would not be complete.

Fig. 5 shows a power-pump fitted with an automatic belt shifting attachment which operates as follows: When the pump has filled the tank, which action closes the discharge water-valve or float-valve, and commences to raise pressure in the discharge pipe, it

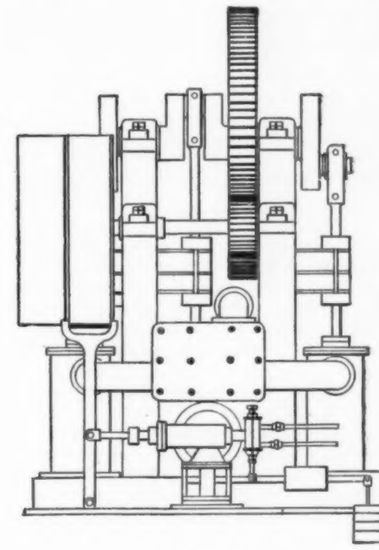


FIG. 5.

is communicated to the small pilot-valve shown in front of the pump. This opens and allows water under high pressure to enter the horizontal cylinder near the valve where it operates on a piston, forcing it to the left hand, carrying the belt-shifter with it, running the belt onto the loose pulley and stopping the pump.

When water is drawn out of the tank, causing the float-valve to open, pressure is at once reduced in the discharge pipe. The weighted lever in front of the pump is lowered, shutting off water from one side of

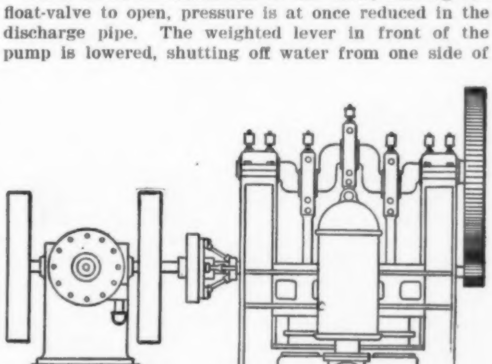


FIG. 6.

the piston and admitting it to the other, thus forcing it to the right hand again, running the belt back on to the tight pulley and starting the pump. This operation is repeated as often as the service requires, and there is no waste of power, as the pump is idle when water is not needed.

This is a triplex pump, and as the cranks are set at 120 degrees, one plunger delivers water after another at equal and short intervals, indefinitely, thus mak-

* Graphite.

ing an almost continuous stream delivered to the tank, which eliminates the shocks and jars due to intermittent action of pumps. This may seem a small matter to engineers who are employed in noisy mills and factories, but it is a large one to those who have charge of office buildings and schools where all noise is objectionable. Dixon's traction belt dressing should be used on these belts, as it will prevent slipping and squeaking, causing the pump to start promptly.

Of course it is possible to run a power pump without this controlling device, but it requires time and care to run the belt off when the tank is full, then to run it on again when more water is wanted. This plan almost always results in the loss of power by pumping water when it is not needed, flooding roofs, etc., also in lack of water due to an empty tank when it is wanted.

In many important buildings no steam is used during the summer and only a low pressure is available in winter. In such cases a gas engine may be used to pump the water, and while it is possible to run a power pump with a belt from an engine of this kind, the same as any other machine would be run, it would then be necessary to start the engine when water is wanted and shut it down when the tank is full, causing much unnecessary care and attention, especially if varying amounts of water are used from time to time.

Fig. 6 illustrates a triple-power pump driven by direct connection to a gas or gasoline engine. There is a clutch between them, however, which may be operated by hand or by means of a special device that stops the pump when the tank is full, and starts it again when more water is needed. If the pump is to be stopped for an hour or more, it is a good plan to stop the engine also, unless it is run to supply power for other purposes. If steady power is wanted, then the automatic clutch should be installed, and it will take care of the water supply without constant watching.

The principle on which this operates is similar to that already described in connection with the belt-shifting device. It is very economical in the use of power, as the pump runs when it is needed and at no other time.

This pump is fitted with seven grease cups in which Dixon's graphite grease may be used to good advantage. These are automatic cups, which feed this grease to keep bearings cool, rather than to wait until they heat enough to cause the grease to melt. This is an important difference that ought not to be overlooked.

HALLEY'S COMET.*

By F. W. Henkel, B.A., F.R.A.S., Late Director of Markree Observatory.

The shortly expected return of this well-known object, which was the first of these bodies known to move in closed paths round the sun, and the remarkable phenomena attending its last appearance (in 1835 and 1836) render Halley's comet a peculiar object of interest at the present time.

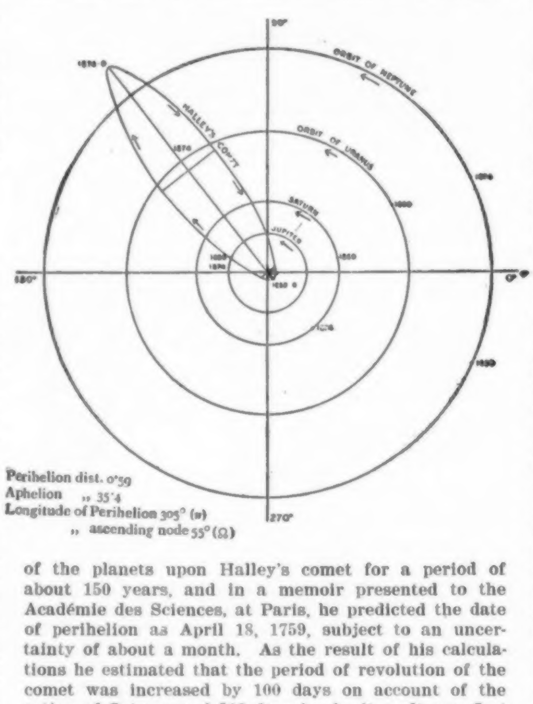
Newton, in the third section of the Principia, first showed that a body moving under the influence of a force varying inversely as the square of the distance from the center of force, will describe one or other of the curves known as the "conic sections," i.e., either an ellipse (or circle, as a special case), a parabola, or a hyperbola. These three curves may all be obtained by cutting a cone in different ways by a plane, but perhaps they may be more intelligibly defined to the non-mathematical reader as obtained by throwing the shadow of a circular disk upon a plane, such as the surface of a table. If, however, the disk is held parallel to the table, we shall get a circle; if it is held edgeways to the light, the shadow will be a straight line. If now we raise our disk so that its highest point is on a level with the source of light, we shall get a curve known as a parabola, which will be oval at one end, but the two sides will open out. If now we hold our disk still higher, we shall get another curve still, whose two sides will separate even farther from one another. This curve is known as the hyperbola.

While the planets move in ellipses, so little differing from circles that if represented on paper the deviation is not perceptible, on the other hand, most comets are found to move in orbits so nearly parabolic that only in a few cases are they known to be otherwise. A great comet which appeared in 1680, and approached very close to the sun, was the first whose path was calculated as a parabola, though there is some reason to believe that it was not truly so, but an enormously elongated ellipse.

In 1682 a comet was observed by Newton, Halley, and others, and on examining the circumstances of its motion, Edmund Halley computed its orbit on the supposition that this was a parabola. Comparing his results with observations of previous comets, for which purpose it was necessary for him to compute their orbits from the necessarily imperfect observations of earlier times, he found that in 1531 and 1607 comets had appeared which followed so nearly the same path as this one that he ventured to assert its identity with them, and to predict its return in a period of about seventy-five years. It was afterward ascertained that comets had been seen in 1066, 1378, and 1456 whose paths were the same as that of the comet of 1682, and it is now known that all these were apparitions of one and the same body. In 1066 its appearance was figured on the Bayeux tapestry, and it was regarded (after the event) as an omen of the Norman conquest. In 1456 the comet is said to have been of extraordinary splendor, its tail 60 degrees long, and it is stated that a papal bull was fulminated against the Turks and the comet, and it was ordained that the bells of all churches should be rung at mid-day. Although Halley had predicted its reappearance, he did not live to observe this himself, dying in 1742, at the age of 83, after having been Astronomer Royal for twenty-three years. He pointed out that the comet must have passed very near the planet Jupiter in the interval between 1607 and 1682, and its velocity increased, thereby resulting in a shortening of its period of revolution. Thus he concluded that, while the interval between 1607 and 1682 was only seventy-five years, the following revolution would probably take a longer time; but the then state of mathematics did not enable him to make the necessary calculations to determine this with accuracy. Were the sun and comet alone existing in space, the latter's path would be an exact ellipse, and the period of its revolution always the same. This is, however, not the case. Besides the sun there are also the planets, and these, by the law of gravitation, attract, and are attracted by, one another, and other bodies. Their masses, however, being very small, in comparison with that of the sun, the general nature of the paths pursued by planets and comets is not changed by this action; but deviations nevertheless arise, which are the more perceptible as their masses are greater and their approaches more close.

Thus Jupiter, the giant planet of our system, whose mass is about 1-1,000 that of the sun, has at times a greater effect on comets when near to him than the sun itself. Lexell's comet of 1770 must have been at one time fifty-eight times less distant from Jupiter than from the sun, and so the planet's attraction ($58^2/1000$ that of the sun) must have been three times greater.

The celebrated Clairaut, who so greatly advanced the science of astronomy by his work on the moon, as well as by his researches in pure mathematics, undertook the great labor of calculating the effect of the action



of the planets upon Halley's comet for a period of about 150 years, and in a memoir presented to the Académie des Sciences, at Paris, he predicted the date of perihelion as April 18, 1759, subject to an uncertainty of about a month. As the result of his calculations he estimated that the period of revolution of the comet was increased by 100 days on account of the action of Saturn, and 518 days by Jupiter. It was first seen by Palitsch, a Saxon peasant, about the end of 1758, and came to perihelion on March 12, 1759, just a month earlier than the time assigned by Clairaut. Before its next return the orbit was calculated by no less than four mathematicians, Damoiseau, Pontécoulant, Rosenberger, and Lehmann, and they all agreed in giving a day in the month of November, 1835, as the time of its perihelion passage. It was first seen at Rome early in August of that year, and was visible up to the 16th of November in the northern hemisphere.

After this, passing its perihelion on that day, it was seen at the Cape and at Melbourne up to the early part of May, 1836, when it finally disappeared from view. Very careful observations and elaborate drawings of its appearance were made by Sir John Herschel, who was then in South Africa. At first it presented the appearance of an almost round nebula, having a bright nucleus not quite at its center. By the beginning of October, 1835, a small tail appeared, and this reached a length of about 20 deg. by the middle of the month. After this the tail diminished, so that before the time of perihelion (November 16) it had again disappeared. On the 2d of October, the day when the tail was first seen, an emission of light was seen coming from the nucleus, on the side presented toward the sun. This emission ceased for a time and then recommenced on the 8th of that month. At this time one observer perceived what he called a "second tail," in a direction opposite to the original tail, thus presented toward the sun. The shape and brightness of the emanations continually varied from the 5th to the 22d of October. At one time two or three emanations were seen to issue in different directions, these having forms sometimes like that of a gas flame coming from a flattened opening, at other times only slightly divergent, and again occasionally only one jet was seen. When more than one such jet or emanation was visible, the principal jet of light oscillated in direction to and fro on either side of the line directed toward the sun, "like a compass needle thrown into vibration and oscillating about a mean position." Sir J. Herschel concluded, from his own observations and those of others, that the matter of the nucleus is largely converted into vapor by the sun's heat, and escapes in jets and streams from the parts turned toward the sun. This matter is, however, prevented from proceeding in this direction by some force directed from the sun, much more powerful than gravitation (and repulsive). Being thus repelled from the sun with considerable velocity, it must leave the nucleus altogether, and, consequently, at each approach the comet must lose a portion of its substance, for the feeble attractive power of the nucleus will prevent this matter being retained within the comet's sphere of attraction, and it will be too far away to be re-absorbed afterward. Thus it is probable that at each apparition the comet will be less conspicuous. After passing its perihelion, the comet was not seen again till near the end of January, when it had no longer a tail, but was seen as a small, round disk, surrounded by a "coma" or nebulous envelope. As the comet gradually receded from the sun this coma disappeared as though absorbed into the disk, and this latter increased greatly in size, so that during one week (from January 25 to February 1) it increased in volume forty times. This increase of size continued, so that mainly from this cause it became invisible, its illumination becoming fainter and fainter as its size increased. The shape of the disk changed gradually from a nearly circular form to that of a paraboloid. The nucleus meanwhile remained nearly unchanged, but the ray or jet proceeding from it increased in length and brightness, its direction being along the axis of the paraboloid. "If," says Herschel, "the office of the jets was to feed the tail, the office of the ray would seem to have been to conduct back its successively condensing matter to the nucleus."

The comet's envelope and ray gradually faded, and as last seen it had the same form as in the previous August, viz., that of a small, round nebula, with a bright point near the center. In all, it was visible from the 5th of August, 1835, to the 5th of May, 1836, a period of nine months.

The period of revolution of this comet is given in Herschel's "Outlines of Astronomy" as 27,865.74 days, so that, since it passed its perihelion on the 15th of November, 1835, it should again return to this position on March 2, 1912; but on account of the considerable disturbing action of the planets Jupiter, Saturn, and Uranus, the actual date may differ considerably from this. So eccentric is the position of the sun in its orbit, that while at perihelion the comet's distance from the sun is about 0.586 of the earth's distance, or about 55 millions of miles, it recedes to a distance of 35.4 times that of our earth, or about 3,300 millions of miles, considerably greater than that of Neptune. While the planets all move in orbits lying nearly in the same plane, the comet's orbit makes an angle of 17 deg. with the ecliptic (plane of the earth's orbit), and its motion therein is in a direction contrary to that of the planets (and of most of the other short period comets), or is retrograde. While the planets move in a direction opposite to the hands of a clock, as seen from our northern latitudes, the comet of Halley moves in the "clockwise" direction (as shown in the accompanying diagram). This comet, as also five others, viz., Pons's comet, seen in 1812 and 1884; Olbers's comet, seen in 1815 and 1887; De Vico's comet of 1846; Brorsen's comet of 1847, and Westphal's comet of 1852, passes near Neptune's orbit at its aphelion, and these comets are sometimes known as Neptune's family of comets. If at any time a comet enters our system from an infinite distance, moving in a parabola under the sun's attraction, it will have its motion either accelerated or retarded when it comes near any of the planets. The smallest increase of velocity will change the parabolic orbit into a hyperbolic one, the smallest decrease will convert it into an ellipse. In the latter case the comet will become a permanent member of our system. This it is possible is what has actually happened, and the converse case of a loss seems also to have occurred. A comet was discovered in 1770, and was shown by Lexell to move in an elliptic orbit, with a short period of about five and one-half years. It was, however, never seen again, nor were any former records of its appearance to be found. Lexell, however, showed that in 1767, when at its aphelion, or farthest from the sun, the comet must have been fifty-eight times nearer to the planet Jupiter than to the sun, and that then the planet's attraction on it was three times that of the sun; that in all probability it had been moving in a parabola, which orbit was converted into an ellipse by the planet's action. He further showed that since the aphelion was close to Jupiter's orbit and the comet's period five and one-half years, that of Jupiter being eleven years, at the end of two revolutions of the comet and one of the planet they would again be close together, 500 times less than their distance from the sun, so that in all probability the comet's orbit would become again parabolic or hyperbolic. Thus he anticipated its eventual disappearance, and, in fact, it was never again seen. Laplace and Leverrier later showed, however, that Lexell's results were liable to considerable uncertainty.

Although, as we have stated, the motion of a comet is greatly affected by the proximity of a planet, the

* Knowledge and Scientific News.

latter, on the other hand, seems quite unaffected.

Thus, the comet of Lexell approached so closely to the planet Jupiter that, had its mass been in any way considerable, both that planet and its satellites would have had their orbits completely changed, the comet's distance from Jupiter being, when nearest, less than that of the fourth satellite (the farthest of those discovered by Galileo in 1610). Nevertheless, not the smallest measurable derangement was observed, so that the mass of the comet must have been much less than that of any of these satellites. This seems to be a general rule, no perturbations due to a comet having been ever perceived for any planet. Yet the volume of some comets being at times greater than that of the sun itself, the density of the materials composing them must be extremely low. This is also evident from other considerations. Small stars have been distinctly seen through the head of a comet, even through the nucleus, without perceptible diminution of brightness. In the case of one comet, known as Encké's, from the name of the discoverer, there is reason to believe that its period of revolution is diminishing gradually, and that it is slowly getting nearer to the sun, as though acted upon by some resistance to its motion. This has been supposed to be due to the "luminiferous ether," but since this retardation seems to have become much less of late years than formerly, and so far no other comet seems to have its motion affected in a similar way, there is considerable doubt about this conclusion. By Kepler's third law, the periodic time of a body moving round the sun is known from its distance from that body. (The squares of the periodic times are as the cubes of the mean distances.) Thus, a resisting medium, by diminishing the comet's velocity, gives the sun more power to draw it toward itself, and so, lessening its distance, causes its period to become shorter. So unless the comet be dissipated by loss of material, it will some day fall into the sun.

Many interesting problems are presented to us by these bodies (of which Halley's comet is one of the most remarkable and interesting). The question as to the existence of a resisting medium, the nature of the repulsive force (supposed by some to be electrical, which is at times much greater than the gravitational attraction), the condition of the matter composing the comas and the tails, and the origin of these bodies, are all matters concerning which we know but little at present. Many recent writers have revived Clerk Maxwell's idea of "radiation pressure" with regard to the phenomena of comets' tails. Light being regarded as an electro-magnetic phenomenon, its incidence on an absorbing substance causes a pressure on the latter. The late Prof. Fitzgerald suggested this light pressure as the cause of comets' tails, and observed that each different gas would give rise to a separate tail, owing to the different size and density of its molecules. Since only a small part of the radiation falling on gases is absorbed by them, Arrhenius supposes that the matter repelled by the light pressure is not gaseous, but rather consists of fine particles, condensed from the gaseous emanations.

In making some further investigations, Schwarzschild arrived at the conclusion that light pressure is sufficient to account for a repulsive force twenty times as great as gravitation on the cometary tails and appendages, but not for a greater amount of force. Since in some cases a repulsive force as much as forty times that of the gravitative attraction has been observed, the light pressure theory is insufficient to account for these. Of other theories as to cometary appendages, we may mention that outlined by Mr. Boys, in his presidential address to Section A of the British Association, 1903. He suggests that radioactive substances in the nucleus may be the cause of these phenomena. If the sun be electrically charged, the rays will be repelled from the nucleus so as to form a tail, and the different kinds of rays given by radio-active substances would give rise to tails of differing curvatures.

It has already been stated that though the mean period of Halley's comet is nearly seventy-seven years, yet, on account of planetary perturbations, the actual interval from one return to the following may differ very considerably from this. In 1862, Dr. Angström published a paper in which he deduced a mean period of 76.93 years from a discussion of all the observed perihelion passages, and stated that this period is affected by two large inequalities. Calculating from his empirical (i.e., observational) formulæ, Mr. Crommelin has obtained the date 1913.08 for the next return to perihelion. The late Comte de Pontécoulant, however, in 1864, published the results of his calculations, giving the date of 1910, May, for the next return, a difference of nearly 2¾ years from Angström's result. Messrs. Cowell and Crommelin, of Greenwich, are at present engaged in independently computing the perturbations of this comet, following Pontécoulant's method, and the present writer has also done a little in this direction. Some obvious errors in the values given by Pontécoulant for the change of eccentricity have been detected, and the perihelion distance is nearly the same (0.59, the earth's distance from the sun being 1.00) as at the last return, whereas Pontécoulant made it considerably greater (0.68). However, they have arrived at the main result, that the time of return given by Pontécoulant (1910, May) is correct within a month, but it may be a few weeks earlier; consequently Angström's curve is altogether wrong for this return. Thus they consider his two inequalities to have a very doubtful existence, and that it is possible many of the earlier returns have been wrongly identified by Hind, whose results Dr. Angström used.

SCIENCE NOTES.

A French scientist, M. Emilien Grimal, in the course of his researches upon the extract of the needles of the Aleppo pine of Algeria, succeeded in isolating phenylethylic alcohol. This alcohol had not heretofore been obtained except in the essences of neroli and roses. When distilled at reduced pressure, the pine essence gave different fractions. The part which passed between 120 and 135 deg. C. at 10 millimeters (0.4 inch) pressure, was entirely saponified by potash and taken up by ether. The latter solution was distilled, and the fraction which boils at 95 to 98 deg. C. (8 millimeters or 0.32 inch pressure) was treated by phthalic anhydride according to Haller's method for extracting terpenic alcohols. The product of the reaction is treated by ether in the presence of an excess of chloride of sodium. Evaporating the ether, he secures a very aromatic liquid distilling at 218 to 220 deg. C. at atmospheric pressure and having the following constants; specific gravity at 15 deg. C., 1.0187; index of refraction at 18 deg. C., 1.52673+. It answers to the formula $C_8H_{10}O$. Oxidizing it with dilute chromic acid, he produces phenyl-acetic acid, while benzoic acid is formed by using permanganate of potash. When treated by iso-cyanate of phenyl, the body gives a phenyl-urethane which crystallizes in fine silky tufts, having the formula $C_{15}H_{15}O_2N$, melting at 79 deg. to 80 deg. C.

The preparation of tetrachloride of titanium forms the subject of researches made by Vigouroux and Arrivaut, of Paris. Seeing that the alumino-thermic process allowed them to obtain alloys of titanium and iron in the laboratory and that these bodies are easily attacked by dry chlorine, it seemed likely that commercial ferro-titanium, which exceeds 55 per cent in the latter metal, would be easily utilized for the purpose. In their first method they treat the alloy directly by chlorine gas after slightly breaking it up. It is put in a porcelain tube in which is running a current of chlorine, the tube being heated by a furnace. At low redness, the action commences with incandescence and the chlorides appear. The ferric component is solidified in the cooler part of the tube, which should be rather large, while the more volatile tetrachloride is liquefied farther on in a condenser. This process is easily carried out, but the presence of ferric chloride has some disadvantages. In the second method they eliminate the most of the iron beforehand. Dissolving out by hydrochloric acid a residue is obtained which has from 80 to 90 per cent of titanium. This is placed in a porcelain tray inside the tube and treated with chlorine gas, as before. Much larger quantities of the product are thus secured. It remains to purify the crude product. The liquid is always colored red by ferric chloride, but by filtering they obtain an orange colored liquid nearly free from iron. A series of fractional distillations gave a perfectly pure body, which boils near 136 deg. C., and is free from chlorine in a free state. It is quite colorless and does not fume when in contact with air, contrary to what has been stated.

A reptile which enjoyed the distinction of having the largest head of any known land animal, either living or dead, is described in Knowledge by Mr. R. Lydekker, F.R.S. This animal, the Triceratops prorsus, or Three-horned Dinosaur, existed both in the New World and the Old; but a nearly complete specimen has been set up by Prof. Marsh in Washington, and a duplicate model is now being mounted at South Kensington. As mounted, the skeleton measures 19 feet 8 inches from the point of the curious, toothless beak to the tip of the tail; while at the loins it stands 8 feet 2 inches. In addition to the skull, which is 6 feet long, or nearly one-third the total length, the most noteworthy features of the skeleton are its great relative height at the loins, the extremely short and deep body (shaped more like that of a mammal than that of a crocodile), the tail and massive limbs, and the curious turtle-like flexure of the fore-feet. In addition to its great absolute and relative size, the skull is specially characterized by the presence of three horns, one in front and two behind; the hind pair being strikingly like the horn-cores of a gigantic ox. Indeed, so ox-like are these horns that a pair was actually described as indicating a Cretaceous bison. Equally peculiar is the presence of a cutting beak, formed by a separate bone in each jaw. More striking still is the presence of a great bony curtain or frill (like the flange of a fireman's helmet) overhanging the neck, and thus rendering the relative length of the skull greater in respect to the rest of the skeleton than it really is. Both the horns and the curtain are considered by Prof. Marsh to have been covered in life with a thick layer of horn.

In an interesting paper Prof. Pickering gives the results of his studies on the forms of the Hawaiian craters, made in 1905, with the object of comparing them with the lunar craters, noting resemblances and differences. The Hawaiian craters, unique upon the earth, appear to bear more resemblances to those of the moon than do the usual terrestrial volcanoes, suggesting the origin of most lunar craters by rise and fall of a central lava column with caving in and engulfment of the walls. Amid much that is valuable, however, it must be noted that hypotheses of origin for the larger craters and the Maria, which at best are founded upon slender evidence and are opposed by very great theoretical physical difficulties, are stated without qualification as facts. Further, it is stated that "rills" and valleys are believed by the writer to be due to water erosion, and ridges, it is thought, may be lateral moraines. Numerous spots which increase in size and darken during the progress of the lunar day are believed to be due to vegetation. The reviewer would suggest, however, in view of the impossibility of observing minute details in the lunar features and the very slight resemblance at best to those of the earth, that such conclusions, involving the presence of liquid and solid water and life upon the moon, are subject to final acceptance or rejection as problems of physics and biology. The testimony of physics is that no way is known by which water in any form could permanently exist upon the moon except in an extremely minute amount, and of biology that organic evolution operating through all geologic time has been unable to develop any kind of vegetation upon the higher terrestrial mountain summits under conditions which there are strong reasons for believing are much more favorable for life than the most favored portions of the lunar surface. These points are to a considerable extent apart from the main thesis of the paper and would not call for special criticism were it not for their far-reaching importance and the fact that in the past few years the pseudo-scientific columns of some papers have given a certain popular currency to these hypotheses stated without reserve as being facts. In conclusion it may be said that this paper marks a step in advance in the study of lunar features, but the reviewer is of the opinion that a better understanding of these selenological enigmas is finally to come from a rigorous analysis, following a method of multiple hypotheses, which shall use to the fullest extent exact mathematical and physical methods.

ELECTRICAL NOTES.

In continuing its research on the inductive capacity of dry paper for telephone cables, a number of samples of pure solid cellulose were tested by the National Physical Laboratory for resistivity and inductive capacity both when air-dry and oven-dried, and also at various temperatures from 15 deg. to 80 deg. C. Many of the tests were by the telephone bridge method (of Nernst and others) in which the capacity and leakage resistance are simultaneously determined. A specially designed microphone hummer giving an alternating current at 2,000 ~ per second was found of great advantage. The inductive capacity of the oven-dried cellulose was found to be about 6.7, that of telephone paper being about 2.0, the much lower value of the latter being due to the large amount of air-space and the relative distribution of the fibers. The resistivity of the well-dried cellulose was of the order of 1,600 million megohm-centimeters at 25 deg. C.; when air-dry it is only about 4 megohm-centimeters and behaves like an electrolytic solution of permittivity about 15. Similar measurements were also made with cellulose acetate, a substance which is now largely used in place of silk for insulating thin wires. From the solution in chloroform, very tough highly insulating films can be obtained; without any artificial drying these showed a resistivity of about 200 million megohm-centimeters at 16 deg. C.

It seems that the problem of applying electric traction upon the trunk lines of the Prussian state railroads is about to have a practical solution. According to the most recent information, preparations are being made to electrify the important line running between Altona and Kiel, which is about 60 miles long, and it is thought that all the trains, both passenger and freight, will be taken by electric locomotives before the end of the present year. The results of this experiment will allow the Berlin authorities to see whether they can extend the use of electric traction to the other through lines of the State railways. On the other hand, it is reported that in order to secure the best possible passenger service with short intervals, a number of electric motor cars are to be put in operation upon certain lines of the Prusso-Hessian railroads. The first of the motor cars, which are to be run by storage battery, are now entirely finished, and they have capacity for sixty passengers seated in third class. They will not have special smoking or baggage compartments but if need be, a separate compartment will be used for second class passengers. One of these cars has been tried not long since in the presence of the Prussian Minister of Public Works, upon the Berlin-Zossen line, and the tests came off very satisfactorily. The present motor cars will soon be placed at the disposal of the Mayence railroad administration, and they are to circulate upon the Mayence-Ingelheim and Mayence-Oppenheim sections.

Three electric locomotives using direct current at high tension have been built at the Siemens-Schuckert Company, of Berlin, for use upon a mine railroad. The locomotives are designed to take the trains containing the ore which are sent from the mines of Sainte-Marie to the metallurgical plant of Maizieres, near Metz. About ten miles is the total length of the line, and the shortest curve has a 200-foot radius. The line is narrow gage of 39 inches. It is expected to run the ore trains at twenty miles an hour. Each of the new electric locomotives weighs 60 tons, and an entire train of ore cars, with the locomotive, represents a weight of 350 tons. The tension of the direct current is high, being no less than 2,000 volts. Each locomotive carries four motors, each one of which is rated at 160 horse-power. The braking, as well as the dumping of the ore cars will be carried out by means of compressed air contained in cylinders. Two air pumps for this purpose are mounted upon the locomotive and are coupled to special electric motors. The bearings of the motor reduction gears are fitted with a pressure oil system of lubrication. From an oil tank are run the oil feed tubes, each provided with a sight-

feed lubricator. The upper part of the main oil tank is connected by suitable piping with the compressed air storage tanks of the locomotive, so that the oil is supplied to the piping at a pressure of seven atmospheres. An overhead trolley line is used for the locomotives. It has a triple insulation and is protected against a rise of voltage or an overload by special fuse blocks. Two substations provide the current which is needed for the line, and there is one of these stations at each end of the track.

ENGINEERING NOTES.

Spitsbergen will soon boast the possession of the farthest north railway. The line is to be built ten degrees farther north than the so-called Lofoten Railway, which crosses the Arctic circle in northern Scandinavia. The object of the new line is to work the coal deposits of Spitzbergen, which are situated in the interior of the island. The line will connect them with the coast. The first plan for an earth surface line was abandoned, owing to the natural difficulties. It is now proposed to construct an aerial suspension railway on the Bleichert system.

The tendency of feed water to cause foaming, after treatment with alkaline reagents, and the difficulty of maintaining a solution containing no floating particles, has caused some trouble. The chief cause for foaming of treated water is the increasing of the surface tension of the liquid by the solution of soda salts, and, as all water under pressure is in a turbulent state, when a release of pressure comes, any substance in solution which increases the surface tension will cause foaming which will be further increased by the addition of fine solid particles in the water.

In Germany it was planned some time ago to build a high-speed electric railway from Berlin to Vienna and to use the various iron smelting plants and collieries located along the road as substations for supplying electric energy to the line. But it was found that there was in most cases an adequate consumption of surplus power in the neighboring districts of these plants, so that there was not enough energy left available for realizing this project. In this country there are in certain localities vastly greater possibilities for operation in the direction indicated.

The chief object of a research now being conducted by the Engineering Department of the National Physical Laboratory of England is to determine the simplest and best method by which a measure of the capacity of a given material to resist shocks can be obtained. It is proposed to carry out a large number of tests on about one dozen samples of steel and iron of the kind in commercial use at the present time. These tests will be made on each of the three impact testing machines which have been already constructed, and on the Izod impact tester lent by Messrs. Avery. The experiments with these four machines will, it is hoped, reveal the relative merits of the "single blow" method and the "repeated blow" method. Concurrently with these tests, statical tests are being made on similar specimens to determine the total work done in fracture, so as to be able to compare the values so obtained with the energy of the blow to cause fracture in the impact test. In the case of the specimens tested on the machine for alternating direct stresses due to impact, it is proposed to subject them to microscopical examination during the progress of the tests and to obtain photographs of the gradual development of the slip lines into cracks. It is hoped that this research will be completed during the present year. It is then proposed, by means of the methods of testing developed in the preceding research, to undertake the investigation of the properties of certain materials which have proved weak under shock without apparent cause. It is further proposed at the same time to investigate the effect of various kinds of heat treatment on resistance to shock in the case of iron and steel.

The ascension of the Puy-de-Dome, which is an isolated mountainous height not far from Clermont-Ferrand, France, and presents a very steep slope, is attended with some difficulties, and numerous projects for a railroad combined with a rack-rail or a cable incline were discussed without arriving at a practical result, either owing to technical or financial reasons. The difference of level is more than 1,000 meters (3,250 feet) and the soil is rather loose in character, which makes it difficult to carry out the work. High winds also increase the drawbacks and special precautions are needed to keep the cars in place. The concession for a line was granted to M. Claret, and it is to run from Clermont-Ferrand to the summit. This line is now running and is quite successful. The method used is that of a set of horizontal wheels running upon a third or central rail. It is more economical than a rack rail. The maximum grades are 120 per 1,000 and the middle rail is used where the grades exceed 60 per 1,000. As to the track, it is 1 meter (39.4 inch) regular narrow gage, using two Vignole rails of fifty-five pounds per yard. The middle rail is supported somewhat above the main rail level upon iron brackets. It has a double rail head and is placed horizontal so as to be clasped by the two locomotive wheels. The rail weight is about the same. Built by the Fives-Lille Company, the rolling stock consists of five steam locomotives, twelve passenger cars, and a freight car. The locomotives are of the standard type, having the extra wheel mechanism fitted on underneath, the total weight being 37 tons. Compressed air is used to press the horizontal wheel against the middle rail. There is a pair of these wheels at each end of the locomotive, lying outside of the three pairs of rolling wheels.

THE

Scientific American Supplement.

PUBLISHED WEEKLY.

Terms of Subscription, $5 a year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.50 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and canvassers.

MUNN & CO., Publishers,

361 Broadway, New York, N. Y.

TABLE OF CONTENTS.